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INHERITANCE OF CERTAIN CHARACTERS IN THE HYBRID OF *MEDICAGO MEDIA* AND *MEDICAGO GLUTINOSA*[1]

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Studies on the inheritance of certain characters in alfalfa grew out of the breeding work of pasture types of alfalfa. Tests with variegated alfalfa, *Medicago media*, have shown that certain varieties developed primarily for hay are more productive and persistent under pasture treatment than others. There are also a number of prostrate growing, stoloniferous species whose value for pasture purposes is being investigated. In recent years a large number of plots from such species have been grown in our introduction nursery in order to assay their breeding value. For the most part these collections belong to *Medicago falcata*. Other species tested were *M. coerulea*, *M. dwazahetica* and *M. glutinosa*. The latter species was used in these inheritance studies.

M. glutinosa[3] is indigenous to the Caucasian regions of the U.S.S.R. Plants typical of the species are prostrate-growing with a slight tendency to creep by stolons. The leaves are small but very profuse. The flowers vary in colour from deep purple to cream with many variegated. The pods are coiled one to two turns and are covered with upright glutinous hairs. Tests showed that while its leafiness and persistence made *M. glutinosa* a promising pasture type, its poor seeding habits would discount its utilization.

It was decided to cross some cream-coloured selections with high seed producing plants from *M. media* in an effort to combine good seeding habit with the valuable glutinosa pasture characters. The plant used in the cross was an autogamous Grimm selection similar to those referred to by Kirk and White (5). This selection, hereafter referred to as Aa 88, was crossed with *M. glutinosa* selections in 1937 and an F_1 generation was grown. Thirteen F_1 plants were selfed and an F_2 population of approximately 1,600 plants was established in 1938. This population was studied in considerable detail in 1939 with the two objects of obtaining promising selections and of studying the mode of inheritance of characters for which the two parents differed. This paper reports the results of these inheritance studies.

INHERITANCE OF FLOWER COLOUR

The flowers of the *M. glutinosa* selections used were cream coloured with the pigment being more intense on the wings and keel than on the standard. Selfed lines and crosses between these plants showed this colour to be true-breeding.

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Aa 88 possessed medium dark purple flowers free from variegation. The distribution for flower colour in the L_1 progeny of Aa 88 is given in Table 1. There is a range of colour extending from light purple to dark purple which might indicate at least two pairs of segregating factors. However, the factorial constitution can best be deduced by examining the F_2 data.

The flower colour of the F_1 plants was variegated. The outer portion of the standard and the tip of keel retained the purple colour while the inner portion of the standard and the lower part of the keel were a deep yellowish cream which gradually blended into the purple.

TABLE 1.—SEGREGATION FOR FLOWER COLOUR IN L_1 OF AA 88 AND F_2 OF AA 88 × *M. glutinosa*

Material	Cream	Light purple	Light purple +	Medium purple	Medium purple +	Dark purple	Very dark purple	Total
L_1 of Aa 88		2	11	45	29	3	—	90
F_2 families								
49 – 2	10	15	1	22	—	2	9	59
50 – 4	21	21	2	25	2	4	5	80
50 – 6	47	38	9	83	9	21	4	211
48 – 3	8	12	—	13	—	2	—	35
48 – 2	16	26	3	36	—	1	—	82
48 – 11	3	46	2	24	—	1	6	82
50 – 2	6	20	7	68	13	23	29	166
48 – 8	2	45	5	102	6	14	29	203
50 – 8	1	50	4	48	4	12	6	125
49 – 4	2	20	24	97	—	18	16	177
51 – 8	0	35	1	48	1	1	—	86
48 – 1	0	13	1	24	4	3	7	52
48 – 5	0	18	2	36	2	7	—	65

In scoring the F_2 population for flower colour, the cream-coloured segregates were easily recognized but in the purple flowered plants it was not found possible to identify variegation (heterozygosity) from selfed purple colours. In all cases, the intensity of the purple colour in the outer portion of the standard in freshly opened flowers was considered and scoring showed a range from light to very intense purple. The data were recorded separately for each F_2 population descended from a selfed F_1 plant. These data are given in Table 1.

In Fisher's Table 111 (3) for $P = 0.05$ and $n = 1$ the chi-square value is 3.841. Since none of the obtained chi-square values exceed this the observed deviations from the fitted ratios are not significant.

It is apparent that the frequencies with which cream-coloured segregates were recovered varies widely in different F_2 populations. This indicates a different factorial constitution for the F_1 plants which in turn must be attributed to the heterozygosity of one or both parents. Table 2 gives the ratio of purple to cream in the different F_2 families. A chi-square test for goodness of fit shows that 5 families fit a 3 : 1 ratio satisfactorily; 2 families fit a 15 : 1 ratio, and 3 families fit a 63 : 1 ratio. In 3 families no cream-coloured segregates occurred. These 3 families probably belong to the 63 : 1 group but the populations were too small for the chance recovery of the recessive type.

TABLE 2.—χ^2 TEST FOR GOODNESS OF FIT IN F_2 FAMILIES OF Aa 88 × *M. glutinosa* TO GENETIC RATIOS

F^2 families	Purple		Cream		Total	χ^2	Ratio fitted
	Observed	Calculated	Observed	Calculated			
49 – 2	49	44.25	10	14.75	59	2.039	3 : 1
50 – 4	59	60	21	20	80	.067	3 : 1
50 – 6	164	158.25	47	52.75	211	.836	3 : 1
48 – 3	27	26.25	8	8.75	35	.086	3 : 1
48 – 2	66	61.50	16	20.5	82	1.317	3 : 1
48 – 11	79	76.87	3	5.13	82	.943	15 : 1
50 – 2	160	155.63	6	10.37	166	1.96	15 : 1
48 – 8	200	198.85	2	3.15	202	.426	63 : 1
50 – 8	124	123.05	1	1.95	125	.470	63 : 1
49 – 4	175	174.24	2	2.76	177	.203	63 : 1
51 – 8	86	—	0	—	86	—	—
48 – 1	52	—	0	—	52	—	—
48 – 5	65	—	0	—	65	—	—

These diverse ratios would indicate that Aa 88 has at least 3 pairs of factors controlling purple flower colour. If all these factors were in the heterozygous condition one would expect the occurrence of the complete recessive segregate, white, in its progeny. From Table 1 it may be seen that in an L_1 population of 90 plants no whites occurred. In a similar autogamous Grimm selection, Aa 85, the L_1 segregated 68 purple to 18 white, indicating white is the recessive of purple and that in this plant there was but 1 pair of segregating factors. The fact that in the progeny test of Aa 88 no plants with white flower colour were recovered indicates that at least 1 pair of purple factors is present in the homozygous dominant condition.

Considering the *M. glutinosa* parent it may be assumed that the factor for cream colour is an allelomorph of one of the purple factors. If it were allelomorphic to a heterozygous pair of factors there should be some families in which white segregates would appear due to the recovery of the complete recessive, but these were not found to occur. If cream were considered allelomorphic to the homozygous pair of purple factors the data fit such a hypothesis fairly well. The following scheme illustrates the hypothesis:—

	Aa 88		*M. glutinosa*	
Factorial Constitution	$P_1P_1P_2p_2P_3p_3$		C C $p_2p_2p_3p_3$	
Gametes produced	$P_1P_2P_3$,	$P_1P_2p_3$,	$P_1p_2P_3$,	$P_1p_2p_3$, C p_2p_3
Constitution of F_1 plants	C $P_1P_2p_2P_3p_3$,	C $P_1P_2p_2p_3p_3$,	C $P_1p_2p_2P_3p_3$	C $P_1p_2p_2p_3p_3$
Ratio expected of	↓	↓	↓	↓
Purple : cream	63 : 1	15 : 1	15 : 1	3 : 1

The discrepancy in the above hypothesis is the fewness of F_2 families that segregate in a 15 : 1 ratio. The 13 F_1 plants from which selfed seed was obtained for carrying on the F_2 lines comprised only a portion of the

F_1 generation of 36 plants, the most vigorous plants being selected. There may therefore have been some discrimination against F_1 plants which would give a 15 : 1 ratio.

In Table 1 the operation of another colour factor or factor interaction is indicated. In some F_2 families there is a class tabulated as intense dark purple. This colour closely matches the Nigrosin Violet of Ridgway's colour chart. Since this colour did not occur in the L_1 progeny of Aa 88 it may be considered as due to the action of an intensifying factor contributed by the *M. glutinosa* parent or as due to factor interaction.

POD HAIRINESS

The hairiness of the pods of *M. glutinosa* plants is very characteristic. The hairs are upright and each exudes a sticky globule at the tip. In Aa 88 the pod hairs were scanty and appressed. In the F_1 generation the glutinosa condition was found to be dominant. The inheritance of hair posture on the pods was studied in the F_2 families. It will be seen that for 10 of the families listed in Table 3 there is a satisfactory fit to a 3 : 1 ratio of upright to appressed hairs. In the last 3 families there was considerable difficulty in tabulating the data as many plants possessed pods on which there was a mixture of upright and appressed hairs. These plants are classified in the Table as intermediate. In these 3 exceptional families the number of plants with appressed hairs on the pods is greatly in excess of the number with upright hairs.

To explain the situation one may assume that *M. glutinosa* carries a dominant factor G for upright hair posture and that Aa 88 carries the recessive g, and in addition is heterozygous for a factor I which partially inhibits the expression of G. Thus the constitution of Aa 88 would be g g I i and *M. glutinosa* G G ii. The F_1 plants would be of two types Gg Ii and Ggii. The latter would give a 3 : 1 ratio in the F_2 of upright to appressed while the former would give an approximate 9 : 4 : 3 ratio for appressed: intermediate: upright. In the last 3 families in Table 3 the observed values do not approximate the calculated values very closely, family 50 – 2 having a chi-square value between $P = 0.05$ and 0.02 for $n = 2$. The poorness of fit to the ratio may be partially due to the difficulty of classification.

TABLE 3.—SEGREGATION FOR HAIR POSTURE ON PODS OF F_2 FAMILIES OF AA 88 × *M. glutinosa*

F_2 Families	Upright		Intermediate		Appressed		Total	Chi-Sq.	Ratio fitted
	Observed	Calculated	Observed	Calculated	Observed	Calculated			
50 – 8	95	93.75	–	–	30	31.25	125	.067	3 : 1
48 – 5	45	41.25	–	–	10	13.75	55	1.364	3 : 1
51 – 8	56	63.75	–	–	29	21.25	85	3.768	3 : 1
48 – 3	27	24.75	–	–	6	8.25	33	.818	3 : 1
49 – 2	40	43.50	–	–	18	14.50	58	1.126	3 : 1
48 – 11	32	37.50	–	–	18	12.50	50	3.227	3 : 1
50 – 4	33	36	–	–	15	12	48	1.000	3 : 1
50 – 6	74	78.75	–	–	31	26.25	105	1.146	3 : 1
48 – 1	37	38.20	–	–	14	12.80	51	.150	3 : 1
48 – 2	77	69	–	–	15	23	92	3.710	3 : 1
48 – 8	23	32.44	49	43.26	101	97.30	173	3.649	3 : 4 : 9
50 – 2	18	24	44	32	66	72	128	6.500	3 : 4 : 9
49 – 4	27	24.37	37	32.50	66	73.13	130	1.602	3 : 4 : 9

GROWTH HABIT

The two parents differed markedly in growth habit or the inclination of the main stems to the ground surface. Aa 88 is semi-upright and segregates in the L_1 generation within very narrow limits indicated a high degree of homozygosity for the character. The glutinosa selections on the other hand were prostrate to semi-prostrate in growth habit. The F_1 plants were semi-prostrate to medium-upright indicating a lack of dominance in inheritance for the character.

TABLE 4.—SEGREGATION OF *M. glutinosa*, L_1 OF AA 88, F_1 AND F_2 GENERATIONS OF AA 88 × *M. glutinosa* FOR GROWTH HABIT

Material	Growth habit				Total
	Prostrate	Semi-prostrate	Medium upright	Semi-upright	
M. glutinosa	6	3	—	—	9
L_1 of Aa 88	—	—	60	30	90
F_1	—	12	1	—	13
F_2 Families					
48 – 8	40	74	43	19	176
48 – 11	24	29	28	3	84
49 – 2	9	15	29	7	60
49 – 4	46	60	44	11	161
50 – 2	52	35	53	23	163
50 – 4	6	13	33	27	79
50 – 6	36	89	67	17	209
50 – 8	19	80	24	—	123
48 – 3	4	10	14	7	35
48 – 1	5	20	20	7	52
48 – 2	14	26	38	16	94
48 – 5	19	23	26	1	69
51 – 8	29	42	15	—	86

In the F_2 families shown in Table 4 there is a distribution from prostrate to semi-upright. Although no factorial analysis appears possible from the data it is evident that some families give a much higher proportion of prostrate growing plants than others indicating different factorial constitutions in the F_1 plants. Although the plants have been grouped into 4 classes there was every gradation of habit, which would show that the character is determined by multiple factors.

STOLONIFEROUS HABIT

Aa 88 is characterized by a crown having no tendency to spread by stolons. *M. glutinosa*, on the other hand, has a definite stoloniferous habit which, however, is fairly variable from plant to plant. Branches tend to bud out below the crown and spread laterally some distance below the ground before emerging. At nodal points on these branches true roots develop. This is considered to be a valuable character for a pasture type of alfalfa since it tends to diffuse the grass and legume better in the sward and is at the same time more resistant to close grazing.

In the F_1 generation the stoloniferous tendency is very slight while in the F_2 families the segregation ranges between the 2 parental types with the majority of plants classed as non-spreading or slightly spreading.

TABLE 5.—SEGREGATION FOR STOLONIFEROUS HABIT IN F_2 FAMILIES OF Aa 88 × *M. glutinosa*

F^2 Family	Strongly spreading	Medium spreading	Slightly spreading	Very slightly spreading	Non-spreading	Total
48 – 8	5	9	54	78	41	187
48 – 11	1	6	22	31	24	84
49 – 2	—	1	9	17	33	60
49 – 4	8	13	52	81	24	178
50 – 2	1	3	31	89	47	171
50 – 4	4	2	19	44	13	82
50 – 6	16	37	53	80	31	217
50 – 8	—	2	6	95	32	135
51 – 8	—	12	22	28	21	83
48 – 3	—	4	8	15	8	35
48 – 1	—	—	13	24	15	52
48 – 2	—	5	22	62	13	102
48 – 5	—	—	20	37	12	69

The distributions for the various F_2 families are given in Table 5. It may be noted that some families are quite dissimilar in their distribution, thus 50 – 6 shows a fairly high proportion of plants in the 2 classes of definite spreading type while 48 – 5 had no plants in these classes. This would indicate that the F_1 plants differ in their factorial constitution probably due to heterozygosity in the *M. glutinosa* parent. While a factorial interpretation is difficult it appears probable judging from the small number of F_2 segregates in the strongly spreading class that more than 2 pairs of factors are concerned, and the skewness of the distribution towards the non-spreading class might indicate partial dominance of non-spreading over the stoloniferous habit.

LEAF CHARACTERS

There is a marked difference in the leaf size and shape of the 2 parents. *M. glutinosa* has a small leaf with the length approximately equal to the width. Aa 88 has a considerably larger leaf with the length about $1\frac{1}{2}$ times the width. On any given plant there is a great diversity of leaf size and shape depending upon the stage of leaf development and the position on the plant. This makes careful sampling necessary. In the leaf measurement recorded here the oldest leaf on a main branch was taken on each plant and the index of leaf shape was determined by calculating the length/width of the central leaflet.

Table 6 summarizes the data on leaf shape for the L_1 of the Aa 88, a few glutinosa plants, the F_1 and F_2 generations. The average leaf shape indices of the F_2 families vary from 1.51 to 1.91. In many cases these differences are statistically significant. This would indicate different factorial combinations for leaf shape in the F_1 plants. In all cases the distributions are approximately unimodal. The character leaf shape appears to be determined by multiple factors.

In the F_2 population, 50 – 6, the degree of correlation between leaf width and length and growth habit was tested. The correlation between leaf length and habit was found to be +0.24; between leaf width and habit +0.35. While small, both correlations are significant and indicate a linkage between some factors for leaf size and habit of growth.

TABLE 6.—SEGREGATION FOR LEAF SHAPE (LENGTH/WIDTH) IN L_1 OF Aa 88, *M. glutinosa*, F_1 AND F_2 GENERATIONS OF Aa 88 × *M. glutinosa*

Material	LEAF SHAPE INDEX											Total	Mean leaf index
	0.8 – 1.0	1.0 – 1.2	1.2 – 1.4	1.4 – 1.6	1.6 – 1.8	1.8 – 2.0	2.0 – 2.2	2.2 – 2.4	2.4 – 2.6	2.6 – 2.8	2.8 – 3.0		
L_1 of 88		1	9	23	29	16	10	3				91	1.70 ± .023
M. glutinosa	4	2	1									7	1.02
F_1		4	7	4	2	5	1					23	1.51 ± .064
F_2 families													
48 – 8		2	18	51	60	36	10	7	2			186	1.69 ± .019
48 – 11		1	2	8	23	24	13	9	5	2		87	1.91 ± .033
49 – 2		1	6	9	12	20	10	2	2			62	1.79 ± .038
49 – 4		1	7	18	40	43	32	13	8	7	4	173	1.88 ± .027
50 – 2	1	5	9	41	47	33	11	4	2			153	1.68 ± .021
50 – 4		1	11	29	21	9	7	3	1	1		83	1.57 ± .038
50 – 6	1	4	11	37	53	62	29	13	5	5	4	224	1.86 ± .037
50 – 8	2	10	17	44	40	24	6	1	1			145	1.60 ± .022
51 – 8		5	5	29	24	20	3	3	1			90	1.67 ± .027
48 – 3		2	4	5	3	10	7	4	2			37	1.82 ± .061
48 – 1		5	7	11	5	5	2					35	1.51 ± .044
48 – 2		6	9	25	32	25	13	5	1	4	1	121	1.75 ± .032
48 – 5	2	4	13	19	16	17	8		2			81	1.63 ± .036

DISCUSSION

Alfalfa is usually regarded as possessing a high degree of heterozygosity which is due to the fact that it is largely a cross-fertilized crop. Stewart (9) who investigated this question found that the progenies from selfed selections taken from several alfalfa varieties show a high degree of uniformity which inclines him to the belief that alfalfa is not as heterozygous as is generally supposed. This in turn he attributes to the tendency to self-fertilization in the crop. It has been a common observation by many breeders of alfalfa that continuous self-fertilization reduces the vigour and survival value of alfalfa, so it is reasonable to assume that the climatic factor would preserve the cross-fertilized and more heterozygous component of an alfalfa variety at the expense of the more homozygous plants derived from self-fertilization.

In inheritance studies with any crop it is desirable to have the parental materials homozygous in order to facilitate a factorial interpretation of the characters studied in the segregating generations. It is difficult to obtain this homozygosity in alfalfa since many plants will be eliminated during the inbreeding process. If we assume a given character is heterozygous at the beginning of the process depending on 3 factors A_1 a_1 A_2 a_2 A_3 a_3, inbreeding may stabilize it in three ways, A_1 A_1 a_2 a_2 a_3 a_3, A_1 A_1 A_2 A_2 a_3 a_3 and A_1 A_1 A_2 A_2 A_3 A_3. Such plants when crossed with the triple recessive would give F_2 ratios indicating that 1, 2, or 3 pairs of factors are involved. One way to overcome such errors in selection of parental material would be to use heterozygous unselfed parents and keep track of the F_2 families derived from several F_1 plants and interpret the results as a whole. This is in essence the back-cross method of studying inheritance.

Several workers have studied the inheritance of flower colour in alfalfa. The cross most frequently examined was *M. sativa* × *M. falcata* involving the purple, blue or violet flower colour of *M. sativa* and the yellow flower colour of *M. falcata*. Waldron (10) and Burton (1) obtained results that indicated that 3 pairs of factors were operative, the F_2 segregates being homozygous purple, homozygous yellow, and heterozygous variegated. They found it impossible to classify the wide range of variegated colours, and the mode of inheritance could only be inferred by setting the proportion of yellow segregates against all other classes which approximated a 1 : 63 ratio.

Lepper and Odland (6) obtained different results from this species cross since in addition to the above colour classes white segregates were obtained. The ratio of purple and variegated : yellow : white was 12 : 3 : 1. The hypothesis proposed by these writers assumed the following factorial constitutions for their material.

Purple	P	P	C	C	A	A	y	y
Yellow	p	p	c	c	a	a	Y	Y
White	p	p	c	c	a	a	y	y

P represents the factor for purple which is epistatic to the factor Y for yellow and C and A are supplementary factors for the production of colour. The factorial constitution of the *M. sativa* plant used by Lepper and Odland was evidently different from those used by Burton and Waldron

and the *M. media* plant used in our cross since in these cases white segregates did not occur in the F_2 population. It was probably similar to plant Aa 85 previously referred to which segregated purple and white in the L_1 progeny.

The posture of the hairs on the pods which differed in the two parents might be classed as a qualitative character inherited in a monofactorial manner with upright hair posture dominant to appressed. The exceptional ratios obtained in 3 F_2 families were explained on the basis of a partial inhibiting factor carried by the Aa 88 parent in a heterozygous condition.

MacVicar (7) studied the inheritance of seed coat colour. White was found to be a simple recessive associated with white flower colour. Black seed coat colour was explained as being conditioned by three pairs of factors incompletely dominant to yellow.

Several investigators have studied a number of characters whose expression is governed by several to many factors and they may be regarded as quantitative in nature. There are the physiological characters, wilt resistance (Brink et al, 2), cold resistance (Peltier and Tysdal, 8), and high seed production (Kirk, 4). Morphological characters of this type are, height, leaf size and shape and root type as reported by Burton (1). The studies reported here on growth habit, stoloniferous habit and leaf characters also confirm the conclusions of Burton that such characters are quantitative.

SUMMARY

1. The inheritance of flower colour, hair posture on the pods, growth habit, stoloniferous habit and leaf shape was studied in the cross *Medicago media* × *M. glutinosa*.

2. The *M. media* parent was postulated as possessing 3 pairs of factors conditioning purple flower colour, of which 1 pair was in the homozygous and the other 2 pairs in the heterozygous condition.

3. The cream colour in the flowers of *M. glutinosa* appeared to be conditioned by a factor pair allelomorphic to the homozygous factor pair in the *M. media* parent.

4. The upright hairiness on the pods of *M. glutinosa* was found to be dominant to the appressed hairy condition on the pods of *M. media*. Several lines with exceptional ratios were explained on the basis of a pair of inhibiting factors.

5. At least 2 pairs of factors appeared to condition growth habit.

6. The stoloniferous habit was conditioned by at least 3 pairs of characters and was partially recessive to non-creeping habit.

7. Leaf size and shape appeared to be dependent upon multiple factors. Leaf length and width were significantly correlated to growth habit.

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THE REPRODUCTIVE CAPACITY OF BREEDS OF RANGE SHEEP[1]

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INTRODUCTION

In the maintenance and improvement of any breed of live stock the reproductive rate is an important factor as it limits the degree of culling and selection that can be practised and affects the income derived from sale of surplus stock. Among domestic animals sheep may be classed as having an intermediate rate of reproduction as multiple births occur with a relatively high frequency.

It is generally acknowledged that lambing percentages are higher in farm flocks than in range bands. This has led to a belief that the breeds used mainly for farm flock purposes are more prolific than the breeds suited to range conditions. The difference may be caused, to a large extent, by factors of environment and management characteristic of the two systems of sheep production. However, consideration must also be given to the possibility that genetic differences in prolificacy exist in the breeds of sheep most suited to the two systems.

REVIEW OF LITERATURE

Kindt (7), in a survey of sheep ranches of Alberta and Saskatchewan, found the average percentage lamb crop to be 75.4% for the two provinces. While this percentage was based on the number of ewes placed with the rams in the fall and the number of lambs at marketing time the following year, and thus is lower than lambing percentage, it does reflect the relatively low reproductive rate of range flocks.

Terril and Stoehr (10) report that 88, 88, 85, and 85%, respectively, of the Corriedale, Targhee, Columbia and Rambouillet ewes in their flock produced lambs. The percentage lamb crop for ewes that actually lambed was 118, 129, 127, and 122 for the breeds in the same order. This gives a calculated lambing percentage on the basis of ewes placed with the rams of 103.8, 113.5, 108.0, and 103.7.

Cooper and Stoehr (2) also report on Rambouillets, Corriedales, and Columbias with percentage of lambs dropped as 99.3, 102.3, and 105.6, respectively, on the basis of ewes bred.

EXPERIMENTAL DATA

The cited reports indicate that under usual range conditions the average lambing percentage for range breeds is not much above 100%. In view of this situation and because of its bearing on range sheep production problems, it was considered desirable to determine whether the deficiency was mainly genetic or more in the nature of environmental influences.

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[2] Assistant Superintendent.

For this study the records at the Dominion Experimental Station, Lethbridge, Alberta, have been examined to determine the reproductive rate in the various breeds and crossbreds at this Station.

As the sheep at the Station are maintained under semi-range conditions, more nearly approaching farm flock conditions during the period of the year when reproductive processes would be affected, it may be expected that the results would very nearly approach the optimum reproductive ability of the ewes. Thus some information can be obtained regarding what may be expected under favourable conditions of nutrition and management. This would indicate what limits might be approached as feed and management conditions on the range are improved.

The data were obtained from the breeding records of the Station flock for the years 1934 to 1940 inclusive. Six groups of sheep are included: namely, New Zealand Corriedales, Canadian Corriedales (a type being bred and developed by the Station), purebred Rambouillets, grade Rambouillets, F_1 crossbreds of Corriedale sires on Rambouillet ewes, and backcrosses of the F_1 to Corriedales. The data for the grade Rambouillets are divided into two sections as some of the ewes were mated to purebred Rambouillet sires and others were mated to Corriedale sires. The ewes in both groups were of the same breeding and general quality.

The data are not equally comprehensive for all groups, but, except for the backcross, are sufficiently so for comparative purposes.

The management of all sheep has been the same throughout the years under consideration so the differences that exist in their performance reflect breed differences.

Table 1 provides a summary of results of breeding for the 7-year period.

TABLE 1.—EWES BRED, ABORTED, BARREN, AND LAMBED IN THE YEARS 1934–40

Breed of ewes	Years of record	Number of ewes bred	Number aborted	Percentage aborted	Number barren	Percentage barren	Number lambed	Percentage lambed
				%		%		%
New Zealand Corriedale	1934–40	172	4	2.3	11	6.4	157	91.3
Canadian Corriedale	1934–40	959	6	0.6	79	8.2	874	91.1
Purebred Rambouillet	1934–40	661	7	1.1	62	9.4	592	89.6
Grade Rambouillet (mated to Rambouillet sires)	1937–40	280	1	0.4	11	3.9	268	95.7
Grade Rambouillet (mated to Corriedale sires)	1936–39	439	1	0.2	36	8.2	402	91.6
F_1	1937–40	228	1	0.4	5	2.2	222	97.4
Backcross	1940	27	0	0.0	1	3.7	26	96.3
		2766	20	0.7	205	7.4	2541	91.9

The data in Table 1 indicate that abortion is not an important factor in determining lambing percentage, though a few early abortions may have been overlooked and such ewes would be included in the barren classification. The abortions constitute less than one per cent of the ewes bred; i.e., ewes placed in the breeding pens.

Barrenness, or failure to conceive, was a much more important factor, and ewes in this classification constitute 7.4% of the ewes bred. All ewes were pen mated and this might be a contributing factor as rams of low fertility would tend to reduce conceptions in certain pens. Distinct differences have been observed in the expressed fertility of rams but no completely sterile rams have been encountered.

The homogeneity of the data was tested by the chi-square test. The procedure used was that given by Snedecor (9) for testing percentage data and yielded a chi-square of 19.62 which for 6 degrees of freedom is beyond the 1% point. Thus it is evident that there are significant differences between breed groups in the percentage of ewes that lamb.

In Table 2 the data are summarized to show the number of lambs in each group and the percentage lamb crop.

TABLE 2.—SUMMARY OF LAMBS BORN AND LAMBING PERCENTAGES FOR THE VARIOUS GROUPS

Breed of ewes	No. of ewes lambed	Total No. of lambs	Lambing percentage *(a)*	Lambing percentage *(b)*
New Zealand Corriedale	157	179	114.0	104.1
Canadian Corriedale	874	1,276	146.0	133.0
Purebred Rambouillet	592	734	124.0	111.0
Grade Rambouillet (mated to Rambouillet sires)	521	757	145.3	136.8
Grade Rambouillet (mated to Corriedale sires)	402	595	148.0	135.5
F_1	222	288	129.7	126.3
Backcross	26	29	111.5	107.4
	2,794	3,858	138.1	126.0

(a) On basis of ewes that actually lambed.
(b) On basis of ewes bred.
NOTE: More grade Rambouillet ewes were included in this table than in Table 1. Complete data were available for this group on the number placed with the rams in the fall and the actual lambing in the spring but for the years 1934 to 1936 the ewes that did not lamb could not be subdivided into abortion and barren groups so they were not included in Table 1.

Two methods have been used for calculating the lambing percentage: namely, *(a)* on the basis of ewes that actually lambed, and *(b)* on the basis of ewes placed with the rams in the fall and still alive at lambing time. The former may be considered to be the more accurate measure of the fecundity of the ewes whereas the latter expresses a summation of the influence of all factors on the yield of lambs. The relative position of the various groups remains the same by both methods of calculation.

The chi-square test was applied to the lambing percentage data *(a)* and it was found that chi-square was 26.36 with 6 degrees of freedom or a value beyond the 1% point. Therefore, the differences are highly significant and may be considered to be real breed differences. The backcross ewes have the lowest percentage, but consideration must be given to the fact that this is a small group, with data for 1 year only, and all the ewes were first lamb ewes. It has been well established that young ewes do not produce as many multiple births as more mature ewes, so consequently a true comparison does not exist between the backcross and the other groups.

Of the remaining groups, for which the data are comparable, the New Zealand Corriedales gave the poorest results, followed by the purebred Rambouillets. No real difference exists between the Canadian Corriedales and the grade Rambouillets. Furthermore, the difference in breed of sires for the two groups of grade Rambouillet ewes apparently has not had a noticeable effect.

Differences in the percentage lamb crop must obviously result from differences in the proportion of single and multiple births. An analysis of the performance of the various groups in the production of multiple births is provided in Table 3.

TABLE 3.—SUMMARY OF COMPLETED PREGNANCIES AND THE DISTRIBUTION OF SINGLE AND MULTIPLE BIRTHS

Breed of ewes	No. of ewes recorded	Number of births					
		Single		Twin		Triplet	
		No.	Percentage of total	No.	Percentage of total	No.	Percentage of total
			%		%		%
New Zealand Corriedale	157	135	86.0	22	14.0	0	0.0
Canadian Corriedale	872	477	54.7	386	44.3	9	1.0
Purebred Rambouillet	588	443	75.3	144	24.5	1	0.2
Grade Rambouillet (mated with Rambouillet sires)	514	275	53.5	235	45.7	4	0.8
Grade Rambouillet (mated with Corriedale sires)	399	206	51.6	190	47.6	3	0.8
F_1	221	154	69.7	67	30.3	0	0.0
Backcross	26	23	88.5	3	11.5	0	0.0
	2,777	1,713	61.7	1,047	37.7	17	0.6

A few ewes conceived to early services of a stray ram on the range one year, and as the lambs were dropped in January and February, and were not in sufficient number to warrant the trouble of keeping them, they were destroyed. No record was kept of the lambs, but the fact that the ewes lambed was recorded. Consequently these individuals could not be included in Table 3 and this accounts for the discrepancy in numbers between Table 1 and Table 3.

The differences in proportion of single and multiple births are what could be expected from the lambing percentages. After eliminating the backcross group the New Zealand Corriedales had the lowest percentage twins, followed by the purebred Rambouillet. The F_1's are intermediate and the Canadian Corriedales and grade Rambouillets have the highest percentage twins.

It is noticeable that in no case does the percentage multiple births reach 50%, though the Canadian Corriedales and the grade Rambouillets approach this figure. Triplets do not constitute an important class of multiple births and no quadruplets were recorded.

The average percentage twins was 37.7 which compares quite favourably with published reports for other breeds, many of which are usually considered to be more prolific. A summary of these reports is presented in Table 4.

These data indicate wide differences both between breeds and within breeds but show that the percentage twins is more often below 50% than above.

TABLE 4.—SUMMARY OF PUBLISHED REPORTS ON PERCENTAGE OF TWINS AND OTHER MULTIPLE BIRTHS IN VARIOUS BREEDS OF SHEEP

Source	Year	Breed	Twins	Triplets	Quadruplets
Heape (4)	1899	Suffolk	52.2		
		Kent	31.4		
		Southdown	18.7		
		Hampshire	24.1		
		Oxford Down	35.0		
		Dorset Horn	37.6		
		Shropshire	46.8		
		Lincoln	29.1		
		Various other pure breds	28.1		
Nichols (6)	1925	Border Leicester	74.5	9.0	
		Leicester	52.5	2.0	
		Suffolk	51.2	2.5	
		Dorset Horn	43.4	3.1	
		Oxford Down	42.3	2.6	
		Lincoln	38.0	2.9	
		Southdown	30.0	0.4	
		Hampshire Down	25.8	0.5	
		Blackface	3.0	0.0	
		Other pure breds	32.9	1.3	
White and Roberts (11)	1927	Welsh Mountain			
		(a) Mountain	2.0		
		(b) Intermediate	6.0		
		(c) Lowland	32.0		
Chapman and Lush (1)	1932	Hampshire	59.8	4.5	
Cremer (3)	1934	East Friesian Milch Sheep	55.2	31.2	2.5
Phillips and Dawson (8)	1937	Southdown	48.6	0.7	
Henning (5)	1939	Southdown	43.4	0.8	

DISCUSSION

The data presented in this paper show quite definitely that breed differences in prolificacy do exist, but that unless the various breeds are kept under similar environmental conditions the genetic differences may be masked. The most striking example of this is provided by the data of White and Roberts (11) for Welsh Mountain sheep. Flocks of this breed, when kept under different conditions: namely, mountain, intermediate, and lowland management, showed wide differences in prolificacy. Likewise the

data for other breeds in Table 4 show wide differences without it being possible to determine whether these are due to environment or strain differences.

That there may be strain differences almost as important as breed differences is indicated by the data from the grade and purebred Rambouillets. The grade Rambouillets may be considered of pure breeding, so the only plausible explanation of the difference in prolificacy is that, as the original sources of the two groups in the Station flock are different, there is a genetic strain difference.

This naturally leads to the question of whether selection in the various breed groups has been a factor in bringing about the differences. Throughout the years that sheep breeding has been in progress at the Station no conscious selection has been made for the twinning characteristic in any breed group. However, in order to determine if there had been an unconscious associated selection in this direction the type of birth of the breeding ewes (i.e., whether born twin or single) was examined. It was found that no significant difference existed in the proportion of ewes born as singles and ewes born as twins other than what would inevitably arise through the greater proportion of twins in one breed group than in another. In fact, there was a greater relative proportion of single ewe lambs retained in the high twinning group than in the low twinning groups, thus indicating that the size and development of the lamb at weaning time favoured the selection of single lambs.

The data indicate that the relatively low rate of reproduction in range sheep cannot be ascribed entirely to genetic characteristics of the breeds. Under the favourable conditions to which the Station flock is subjected prolificacy attains a fairly high level. Therefore, it may be assumed that as the conditions of nutrition and management of range sheep are improved the rate of reproduction may approach that of most of the mutton breeds.

SUMMARY

1. The rate of reproduction for 6 breeds and crosses of sheep was studied. The breeds were: New Zealand Corriedale, Canadian Corriedale, purebred Rambouillet, grade Rambouillet, F_1, and backcross.

2. Significant differences were found in the percentage of bred ewes that lambed.

3. Abortion was not an important factor in reducing the number of ewes that lambed.

4. Barrenness was more important, and an average of 7.4% of all the ewes failed to bear lambs.

5. Significant differences between breeds were found in the percentage lamb crop. The average lambing percentage on the basis of ewes that lambed was 138.1% and on the basis of ewes bred it was 126.0%.

6. The differences in lambing percentage were caused by differences in the proportion of single and multiple births in the various groups. The average percentage singles was 61.7% with a high of 88.5% for the back-

cross and a low of 51.6% for the grade Rambouillets mated to Corriedale sires. Triplets constituted only 0.6% of the total births and no quadruplet births were recorded.

7. A summary is provided of published reports on rate of twinning in a number of breeds.

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DIGESTIBILITY STUDIES WITH FOXES[1]

I. EFFECT OF THE PLANE OF NUTRITION UPON THE DIGESTIBILITY OF MEATS

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INTRODUCTION

Aside from general nutritional interest, the problem of digestibility of feeds by foxes in captivity is of considerable economic importance. With the expansion of the fox ranching industry, and the proportionate decrease in the price of fox pelts, the question of cheaper rations became more pressing. Many meat, fish and cereal products which had not been previously used in fox rations were substituted for more popular and expensive ingredients. The criterion of the suitability of these rations is for the most part the condition of the animal, with especial reference to the fur and reproduction. Obviously other husbandry may modify the end results. This has led to the present multitude of feeding methods in the fox industry, many of which meet with indifferent success both from the nutritional and economic aspects.

In order to formulate balanced rations on the basis of digestible nutrients, as is the commonly accepted practice in animal production, a comprehensive knowledge of the digestibility of fox feeds is necessary. The only published work on this problem is that of Shitkova (4). Two foxes were used and fed rations of beef, horsemeat and beef plus cereal. The cages had smooth wooden floors and the faeces were collected by means of wooden shovels. No attempt was made to collect the urine, which was allowed to drain off in a trough at the side. With rations fed at 200 grams per fox per day, Shitkova obtained average digestibility of 92.50% for beef protein, and 91.73% for beef fat; for horsemeat the corresponding figures are 89.56 and 71.35%.

As a step toward establishing feeding standards for foxes, the Experimental Farms Service of the Dominion Department of Agriculture drew up, in 1936, a series of projects designed to investigate:

1. The digestibility of individual feeds.
2. The effect upon digestibility of:
   - *(a)* various methods of processing feeds;
   - *(b)* plane of nutrition;
   - *(c)* association of feeds;
   - *(d)* age of the animals.

This, the first paper in the series, reports experiments on the effect of the plane of nutrition upon the digestibility of fresh beef, frozen horsemeat, and frozen beef; the data also allow a comparison of the digestibility of these three meats.

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EXPERIMENTAL PROCEDURE

Animals

The experiments were conducted with pedigreed silver foxes, born and raised at the Dominion Experimental Fox Ranch. All were apparently healthy and free from parasites. The 4 animals used in the fresh beef experiment were nearly 2 years old, in the frozen horsemeat experiment three were 2 years and one 4 years, in the frozen beef experiment three were 2 years and one 3 years.

Metabolism Cages

The battery of 4 cages as used at the Dominion Experimental Fox Ranch is shown in Figure 1. A detailed description will be found elsewhere (6). However, a minor modification was found necessary to prevent loss of urine. After the door of the cage is closed the top screen is raised so that the flange meets the inside walls of the cage and the screen is held in that position by 4 stout iron pins (about 4″ long) which pass through the corner posts and under the screen for about 2″. This may be seen in cage C as shown in Figure 1.

Rations

The meats were purchased in the open market from fox feed dealers.

In arriving at the various levels, the limiting factor was the amount the animals would consistently consume. This varies seasonally which accounts for the levels varying with the experiments. For example, animals which would eat about 18 ounces in December would not take over 10 ounces in late February.

FIGURE 1.—Battery of 4 cages used in feeding studies.

The rations were prepared as follows. The meat was ground and 10 rations for each of the different levels were weighed, wrapped in heavy wax paper, and stored in the refrigerator until fed. At regular intervals during the weighing of the rations, 4 samples of 150 grams each were taken, composited and immediately sampled for the dry matter and nitrogen determinations; the remainder dried, ground and analyzed for the ash and ether extract content. The rations were examined before being fed and if any decomposition was evident, discarded and a new sub-period initiated. This occurred with the fresh beef only, in Periods 1 and 2, in each of which the feeding is by two sub-periods as will be seen by Table 13 of the appendix.

Collection and Sampling of the Faeces

The faeces were collected daily and stored in the cold in glass bottles (sealers) with the addition of a few drops of chloroform. At the end of the period the composites were sampled for the dry matter and nitrogen determinations and the remainder dried and ground for the ash and ether extract analyses. Usually, however, the amount of faeces was so small that the residue from the dry matter determinations had to be ground and used to determine the ash and ether extract.

EFFECT OF THE PLANE OF NUTRITION UPON THE DIGESTIBILITY OF FRESH BEEF

The experiment was completed in 4 periods of 10 days, with 10 days between trials. The trial periods were further divided into 3-day preliminary feeding and 7-day collection periods. the collection period starting simultaneously with the feeding of the animals on the fourth day. Experiments in this laboratory demonstrated that markers fed with meat appeared in the faeces about 18 hours after ingestion and had been completely passed in 24 hours, so 3 days preliminary feeding seemed sufficient. The 4 levels of feeding adopted were 280, 340, 400, and 460 grams per day. These, randomized among the 4 animals and with the 4 periods were set up in a 4 × 4 latin square, as shown in the schedule of digestion trials.

TABLE 1.—DIGESTIBILITY OF FRESH BEEF—SCHEDULE OF DIGESTION TRIALS (COLLECTION PERIOD OF 7 DAYS)

Period No.	Dates of collection period	Grams per day			
		Animal A	Animal B	Animal C	Animal D
	1936				
1	Oct. 20 – Oct. 26	340	460	280	400
2	Nov. 10 – Nov. 16	400	340	460	280
3	Dec. 1 – Dec. 7	460	280	400	340
4	Dec. 21 – Dec. 27	280	400	340	460

Results

In Table 2 the coefficients of digestibility for the individual nutrients are arranged by animals and periods. Table 3 gives the mean coefficients at the various levels of feeding. The analysis of the variance is given in Table 4.

TABLE 2.—DIGESTIBILITY OF FRESH BEEF—COEFFICIENTS OF DIGESTIBILITY ARRANGED BY PERIODS AND ANIMALS

—	Period No.	Animal A	Animal B	Animal C	Animal D	Means
Dry matter	1	II 97.9	IV 98.0	I 98.0	III 98.0	98.0
	2	III 97.2	II 96.5	IV 97.7	I 96.5	97.0
	3	IV 96.4	I 96.8	III 97.9	II 97.4	97.1
	4	I 97.7	III 98.0	II 97.4	IV 97.1	97.6
	Means	97.3	97.3	97.8	97.3	97.4
Organic matter	1	II 98.1	IV 98.2	I 98.2	III 98.3	98.2
	2	III 97.4	II 96.8	IV 97.9	I 96.6	97.2
	3	IV 96.7	I 97.1	III 98.1	II 97.7	97.4
	4	I 97.9	III 98.2	II 97.7	IV 97.4	97.8
	Means	97.5	97.6	98.0	97.5	97.7
Nitrogen	1	II 98.4	IV 98.3	I 98.4	III 98.3	98.4
	2	III 97.8	II 97.4	IV 97.9	I 97.3	97.6
	3	IV 97.2	I 96.7	III 97.8	II 97.4	97.3
	4	I 98.1	III 98.4	II 97.9	IV 97.6	98.0
	Means	97.9	97.7	98.0	97.8	97.8
Ether extract	1	II 99.3	IV 99.0	I 98.5	III 99.4	99.1
	2	III 98.2	II 97.8	IV 99.1	I 97.6	98.2
	3	IV 98.4	I 98.9	III 99.3	II 98.9	98.9
	4	I 98.5	III 99.3	II 99.1	IV 98.6	98.9
	Means	98.6	98.8	99.0	98.6	98.8

N.B. Planes of Nutrition designated by roman numerals. I—280 grams per day; II—340 grams per day; III—400 grams per day; IV—460 grams per day.

In this experiment the digestibility for all nutrients was not affected by the plane of nutrition. The variance due to the animals was negligible, but for the nitrogen, that contributed by the periods was statistically significant with respect to the error.

There are two possible explanations of this. The meat perhaps varied in quality, that is to say connective tissue, from period to period. Then in periods 2 and 3 bowel laxity was noted, more so than in 1 and 4. This is probably the meaning of the small differences (max. 1.1%). All rations were completely consumed. The experimental data are found in Tables 13 and 14 of the Appendix.

EFFECT OF THE PLANE OF NUTRITION UPON THE DIGESTIBILITY OF FROZEN HORSEMEAT

When this experiment was begun, the intention was to have the same design and levels of feeding as in the fresh beef experiment. However, in the first and second periods certain animals showed failing appetite, so for the third and fourth periods the rations were adjusted to amounts readily consumed. This meant the sacrifice of the latin square design. Therefore, as conducted, the experiment consists of duplicate trials at 8 levels, these are, 180, 220, 240, 280, 300, 340, 400 and 460 grams per day as shown in the schedule of digestion trials, Table 5.

TABLE 3—DIGESTIBILITY OF FRESH BEEF—MEAN COEFFICIENTS AT THE VARIOUS LEVELS OF FEEDING

	Planes			
	I	II	III	IV
Dry matter	97.3	97.3	97.8	97.3
Organic matter	97.5	97.6	98.0	97.6
Nitrogen	97.6	97.8	98.1	97.8
Ether extract	98.4	98.8	99.1	98.8

TABLE 4.—DIGESTIBILITY OF FRESH BEEF—STATISTICAL ANALYSIS OF DATA AS ARRANGED BY PLANES, ANIMALS AND PERIODS

	Variance due to	Degrees of freedom	Sums squares of deviations	Variance	$\frac{1}{2}$ Log e V	Z
Dry matter	Plane	3	0.73	0.24	−0.714	0.000
	Animal	3	0.64	0.21	−0.781	*
	Period	3	2.43	0.81	−0.106	0.608
	Error	6	1.43	0.24	−0.714	
	Total	15	5.23			
Organic plane	Plane	3	0.71	0.23	−0.735	0.045
	Animal	3	0.59	0.20	−0.805	*
	Period	3	2.44	0.81	−0.106	0.675
	Error	6	1.28	0.21	−0.781	
	Total	15	5.02			
Nitrogen	Plane	3	0.44	0.15	−0.949	0.314
	Animal	3	0.31	0.10	−1.152	0.111
	Period	3	2.63	0.88	−0.064	1.199
	Error	6	0.49	0.08	−1.263	
	Total	15	3.87			
Ether extract	Plane	3	0.92	0.31	−0.586	0.149
	Animal	3	0.40	0.13	−1.020	*
	Period	3	1.80	0.60	−0.256	0.479
	Error	6	1.36	0.23	−0.735	
	Total	15	4.48			

Variance analyzed according to Fisher (1) at $n_1 = 3$ and $n_2 = 6Z$ for P of 0.05 = 0.7798. Z for P of 0.01 = 1.1401.

* Variance smaller than that due to error.

TABLE 5.—DIGESTIBILITY OF FROZEN HORSEMEAT (SCHEDULE OF DIGESTION TRIALS)

Period No.	Dates of collection period	Grams per day			
		Animal A	Animal B	Animal C	Animal D
	1937				
1	Jan. 9 – Jan. 15	340	460	280	400
2	Feb. 5 – Feb. 11	400	340	460	280
3	Mar. 5 – Mar. 11	300	180	260	220
4	April 2 – April 9	180	260	220	300

The periods were similar to those described in the previous experiments.

The data in Table 6, which gives the coefficients for the 8 levels, demonstrate equally efficient utilization at all planes for the dry matter, organic matter, and nitrogen. In the ether extract there seems to be a better utilization at the higher levels but the general distribution of the values is such that any significance is doubtful.

TABLE 6.—DIGESTIBILITY OF FROZEN HORSEMEAT

	Coefficients of digestibility arranged by planes of nutrition								
	I (180 gm.)	II (220 gm.)	III (260 gm.)	IV (280 gm.)	V (300 gm.)	VI (340 gm.)	VII (400 gm.)	VIII (460 gm.)	Means
Dry matter	95.0	92.6	90.1	93.2	92.5	94.4	94.3	96.1	93.5
	93.0	93.4	95.2	91.2	93.9	94.3	93.7	91.6	93.3
Mean	94.0	93.0	92.7	92.2	93.2	94.4	94.0	93.8	93.4
Organic matter	95.2	92.9	90.6	93.8	92.9	94.8	94.6	96.3	93.9
	93.5	93.9	95.3	91.5	94.1	94.9	94.0	91.8	93.6
Mean	94.3	93.4	93.0	92.7	93.5	94.9	94.3	94.1	93 8
Nitrogen	95.9	94.3	93.7	93.6	94.5	95.1	94.3	96.3	94 7
	94.7	94.3	95.8	91.5	94.3	94.7	94.8	92.6	94 1
Mean	95.3	94.3	94.8	92.6	94.4	94.9	94.6	94.5	94 4
Ether extract	95.4	92.7	85.1	98.3	93.9	98.6	98.6	98.7	95.2
	92.8	95.8	97.0	93.9	97.8	96.2	95.2	97.0	95.7
Mean	94.1	94.3	91.1	96.1	95.9	97.4	96.9	97.9	95 5

The rejected feed was collected, dried and analyzed and allowed for in the calculation of the coefficients. The chemical composition of the ration, rejected feed, and calculation of the digestion coefficients are found in Tables 15, 16 and 17 of the Appendix.

EFFECT OF THE PLANE OF NUTRITION UPON THE DIGESTIBILITY OF FROZEN BEEF

The design of this experiment was similar to that for the fresh beef except the levels of feeding which were 175, 225, 275, and 325 grams per day. The trials were conducted during the winter and spring of 1937 and the failing appetite, noted before, again was in evidence. Rejected feed was treated as in the previous experiment.

Table 7 gives the schedule of the digestion trials. In Table 8 the coefficients are arranged by animals and periods. Table 9 shows the average coefficients at each plane. Table 10 presents the statistical analysis of the data in Tables 8 and 9.

For all nutrients the plane was without effect upon the digestibility. There was no significant effect attributable to animals or periods for the dry matter, organic matter or nitrogen.

In the ether extract the animals and periods contributed the greater part of the variance while the fraction for the error was negligible. This produced a statistically highly significant effect for animals and periods although the absolute values are only 1.1 and 1.0% respectively.

TABLE 7—DIGESTIBILITY OF FROZEN BEEF (SCHEDULE OF DIGESTION TRIALS)

Period No.	Dates of collection periods 1937	Grams per day			
		Animal A	Animal B	Animal C	Animal D
1	Feb. 20 – Feb. 26	275	225	325	175
2	Mar. 19 – Mar. 25	325	175	275	225
3	April 17 – April 23	175	275	225	325
4	May 5 – May 11	225	325	175	275

TABLE 8.—DIGESTIBILITY OF FROZEN BEEF—COEFFICIENTS OF DIGESTIBILITY ARRANGED BY ANIMALS AND PERIODS

	Period No.	Animal A	Animal B	Animal C	Animal D	Means
Dry matter	1	III 97.2	II 95.5	IV 96.0	I 95.9	96.2
	2	IV 97.1	I 95.1	III 96.6	II 96.0	96.2
	3	I 98.4	III 95.3	II 96.2	IV 95.1	96.3
	4	II 96.0	IV 95.8	I 95.9	III 96.0	95.9
	Means	97.2	95.4	96.2	95.8	96.2
Organic matter	1	III 97.2	II 95.9	IV 96.4	I 96.4	96.5
	2	IV 97.5	I 95.5	III 96.8	II 96.4	96.6
	3	I 98.5	III 95.6	II 96.6	IV 95.5	96.6
	4	II 96.3	IV 96.1	I 96.2	III 96.2	96.2
	Means	97.4	95.8	96.5	96.1	96.5
Nitrogen	1	III 97.8	II 95.5	IV 96.8	I 96.8	96.7
	2	IV 98.0	I 96.0	III 97.2	II 97.6	97.2
	3	I 98.3	III 96.2	II 96.5	IV 95.5	96.6
	4	II 97.2	IV 97.1	I 96.7	III 96.7	96.9
	Means	97.8	96.2	96.8	96.7	96.9
Ether extract	1	III 98.9	II 97.6	IV 98.3	I 98.1	98.2
	2	IV 98.9	I 97.9	III 98.7	II 98.0	98.4
	3	I 99.3	III 98.1	II 98.5	IV 97.7	98.4
	4	II 97.6	IV 96.6	I 97.8	III 97.6	97.4
	Means	98.7	97.6	98.3	97.9	98.1

N.B. Planes represented by roman numerals. I—175 grams per day; II—225 grams per day; III –275 grams per day; IV—325 grams per day.

TABLE 9.—DIGESTIBILITY OF FROZEN BEEF—MEAN COEFFICIENTS AT THE VARIOUS LEVELS OF FEEDING

	Planes			
	I	II	III	IV
Dry matter	96.3	95.9	96.3	96.0
Organic matter	96.7	96.3	96.5	96.4
Nitrogen	97.0	96.7	97.0	97.0
Ether extract	98.3	97.9	98.3	97.9

TABLE 10—DIGESTIBILITY OF FROZEN BEEF—STATISTICAL ANALYSIS OF DATA AS ARRANGED BY PLANES, ANIMALS AND PERIODS

—	Variance due to	Degrees of freedom	Sums of squares of deviations	Variance	$\frac{1}{2}$ Log e V	Z
Dry matter	Plane	3	0.47	0.16	−0.917	*
	Animals	3	6.94	2.31	−0.416	0.715
	Period	3	0.25	0.08	−1.263	*
	Error	6	3.30	0.55	−0.299	
	Total	15	10.96			
Organic matter	Plane	3	0.27	0.09	−1.204	*
	Animals	3	5.67	1.89	0.318	0.675
	Period	3	0.33	0.11	−1.104	*
	Error	6	2.85	0.48	−0.367	
	Total	15	9.12			
Nitrogen	Plane	3	0.19	0.06	−1.407	*
	Animals	3	5.66	1.89	0.318	0.582
	Period	3	0.77	0.26	−0.674	*
	Error	6	3.54	0.59	−0.264	
	Total	15	10.16			
Ether extract	Plane	3	0.65	0.22	−0.757	0.741
	Animals	3	2.98	0.99	−0.005	1.493
	Period	3	2.68	0.89	−0.059	1.439
	Error	6	0.27	0.05	−1.498	
	Total	15				

Variance analyzed according to Fisher (1) at $n_1 = 3$ and $n_2 = 6$; Z for P of 0.05 = 0.7798; Z for P of 0.01 = 1.1401.

* Variance smaller than that due to error.

Animal A consistently gave the highest coefficients for all nutrients; animal B nearly as consistently the lowest, while animals C and D varied their position from period to period. This is not unusual in animal experimentation.

The variance in the periods is due to the lower values obtained in period 4. Table 18 of the Appendix shows that the ration for this period had a much smaller fat content than the rations for the other periods, and perhaps at this level of fat intake the alimentary contribution to the ether extract of the faeces was sufficient to account for the apparently lower digestibility.

The experimental data will be found in Tables 18, 19 and 20 of the Appendix.

COMPARISON OF THE DIGESTIBILITIES OF FRESH BEEF, FROZEN HORSEMEAT AND FROZEN BEEF

As the plane of nutrition did not affect the digestibility, the values for each meat may be considered replications and the digestibility compared on that basis. Table 11 presents the average chemical composition and digestibility of the three meats. Table 12 compares the variance between the meats with that within the meats and gives the necessary differences for significance at the 5% point.

TABLE 11.—AVERAGE COMPOSITION AND DIGESTIBILITY OF MEATS TESTED (COEFFICIENTS OF DIGESTIBILITY IN PERCENT)

Ration		Nutrients			
		Dry matter	Organic matter	Protein	Ether extract
		%	%	%	%
Fresh Beef	Analysis	29.49	28.52	20.75	7.54
	Digestibility	97.4	97.7	97.8	98.7
Frozen Horsemeat	Analysis	26.86	25.95	21.63	4.42
	Digestibility	93.4	93.8	94.4	95.4
Frozen Beef	Analysis	27.94	27.01	21.25	5.79
	Digestibility	96.1	96.4	96.9	98.1

TABLE 12.—COMPARISON OF FRESH BEEF, FROZEN HORSEMEAT AND FROZEN BEEF. ANALYSIS OF VARIANCE

Nutrient		Sum of squares	Degrees of freedom	Variance	Z	Necessary difference
Dry matter	Between meats	133.60	2	66.80	2.0225	0.8
	Within meats	52.86	45	1.17		
	Total	186.46	47			
Organic matter	Between meats	125.80	2	62.90	2.0186	0.7
	Within meats	49.80	45	1.11		
	Total	175.60	47			
Nitrogen	Between meats	98.98	2	49.49	2.0688	0.6
	Within meats	35.60	45	0.79		
	Total	134.58	47			
Ether extract	Between meats	98.32	2	49.16	1.2346	1.4
	Within meats	187.18	45	4.16		
	Total	285.50	47			

For $n_1 = 2$ and $n_2 = 45$, $Z = 0.5824$ at P 0.05; $Z = 0.8156$ at P 0.01.
Necessary difference between two means = ($t \times$ standard error of difference between two means).

The meats were highly digestible, particularly the fresh beef. The frozen horsemeat gave lower values than the other two for all nutrients, and the fresh beef was superior to the frozen beef except in the ether extract. To attempt to consider at length why these meats differ in apparent digestibility is beyond the scope of this paper. It is possible however, that the amount of albuminoid proteins is a factor. Mitchell, Beadles and Kruger (2) working with rats found the biological value of connective tissue to be much lower than muscle. Their data revealed that the connective tissue was less digestible. Pittman, McCammon and Holman (3) found in the human that the nitrogen of the more tender cuts of beef was slightly better utilized. *In vitro* experiments of Smorodintzev and Adova

(5) show that high collagen content decreases the digestibility of beef. It is to be expected that horsemeat would contain more connective tissue than beef. The frozen beef is essentially carcass trimmings and it probably contains more connective tissue than the fresh beef as purchased.

SUMMARY

1. Digestibility was determined at various planes of nutrition for fresh beef, frozen horsemeat, and frozen beef.

2. The digestibilities of the dry matter, organic matter, nitrogen, and ether extract were not affected by the plane of nutrition.

3. With the fresh beef the periods were the greatest contributors to the variance.

4. With the frozen beef the animals were the greatest contributors to the variance.

5. The descending order of the digestibility of the three meats is (1) fresh beef, (2) frozen beef, (3) frozen horsemeat.

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APPENDIX

TABLE 13.—DIGESTIBILITY OF FRESH BEEF—DATA FOR CALCULATION OF COEFFICIENTS (COLLECTION PERIOD 7 DAYS)

—	Animal No.	Original weight of feeds or faeces	Nutrients			
			Dry matter	Organic matter	Nitrogen	Ether extract
		gm.	gm.	gm.	gm.	gm.
Period 1—						
In fresh beef (grams)	A	2380	751.0	726.2	81.5	181.2
	B	3220	1015.0	982.6	112.1	248.0
	C	1960	618.4	598.0	67.2	151.0
	D	2800	883.4	853.3	95.8	215.6
In faeces (grams)	A	60	15.9	13.8	1.3	1.3
	B	95	20.8	18.0	1.9	2.4
	C	32	12.3	10.5	1.1	2.3
	D	69	17.7	14.9	1.6	1.3
Coefficients, %	A		97.9	98.1	98.4	99.3
	B		98.0	98.2	98.3	99.0
	C		98.0	98.2	98.4	98.5
	D		98.0	98.3	98.3	99.4
Period 2—	A	2800	822.6	794.0	85.5	240.0
In fresh beef (grams)	B	2380	699.3	674.8	72.7	203.4
	C	3220	946.1	913.0	98.3	276.0
	D	1960	575.9	555.7	59.9	168.0
In faeces (grams)	A	84	23.1	20.4	1.9	4.3
	B	87	24.3	21.9	1.9	4.5
	C	91	21.9	18.9	2.1	2.5
	D	74	20.4	18.1	1.6	4.1
Coefficients, %	A		97.2	97.4	97.8	98.2
	B		96.5	96.8	97.4	97.8
	C		97.7	97.9	97.9	99.1
	D		96.5	96.6	97.3	97.6
Period 3—	A	3220	958.6	931.6	195.3	269.8
In fresh beef (grams)	B	1960	583.5	566.4	64.1	164.1
	C	2800	833.7	809.9	91.6	234.6
	D	2380	708.7	688.5	77.8	199.4
In faeces (grams)	A	109	34.7	31.1	2.9	4.3
	B	106	18.4	16.4	2.1	1.8
	C	70	17.8	15.6	2.0	1.7
	D	79	18.3	15.9	2.0	2.1
Coefficients, %	A		96.4	96.7	97.2	98.4
	B		96.8	97.1	96.7	98.9
	C		97.9	98.1	97.8	99.3
	D		97.4	97.7	97.4	98.9
Period 4—	A	1960	496.1	479.6	69.6	74.5
In fresh beef (grams)	B	2800	708.7	685.2	99.4	106.7
	C	2380	602.4	582.7	84.5	90.7
	D	3220	815.0	787.9	114.3	122.7
In faeces (grams)	A	37	11.6	10.2	1.3	1.1
	B	53	14.1	12.3	1.6	0.6
	C	58	15.8	13.5	1.8	1.0
	D	110	23.8	20.7	2.8	2.0
Coefficients, %	A		97.7	97.9	98.1	98.5
	B		98.0	98.2	98.4	99.3
	C		97.4	97.7	97.9	99.1
	D		97.1	97.4	97.6	98.6

TABLE 14.—DIGESTIBILITY OF FRESH BEEF—CHEMICAL COMPOSITION OF THE RATION AS FED

Period		Dry matter	Organic matter	Nitrogen	Protein N×6.25	Ether extract	Ash
		%	%	%	%	%	%
1	Sample 1 fed 5 days	32.08	31.06	3.36	21.00	7.95	1.02
	Sample 2 fed 2 days	30.23	29.14	3.59	22.42	7.08	1.09
2	Sample 1 fed 3 days	32.57	31.68	3.03	18.92	12.00	0.89
	Sample 2 fed 4 days	26.99	25.86	3.07	19.14	6.00	1.13
3		29.77	28.93	3.27	20.44	8.38	0.84
4		25.31	24.47	3.55	22.19	3.81	0.84

TABLE 15.—DIGESTIBILITY OF FROZEN HORSEMEAT (CHEMICAL COMPOSITION OF THE RATIONS AS FED)

Period	Dry matter	Organic matter	Nitrogen	Protein N × 6.25	Ash	Ether extract
	%	%	%	%	%	%
1	25.45	24.57	3.65	22.81	0.88	2.97
2	27.46	26.57	3.48	21.75	0.89	4.86
3	28.10	27.16	3.28	20.50	0.94	4.98
4	26.41	25.48	3.42	21.38	0.93	3.86

TABLE 16.—DIGESTIBILITY OF FROZEN HORSEMEAT—CHEMICAL COMPOSITION OF REJECTED RATION

Animal period and amount	Dry matter	Organic matter	Nitrogen	Protein N × 6.25	Ash	Ether extract
	%	%	%	%	%	%
A. Period III 154 gm.	95.81	92.24	11.80	73.75	3.57	14.81
B. Period II 135 gm.	95.77	91.52	11.32	70.75	4.25	13.90
C. Period II 74 gm.	94.60	89.66	11.79	73.69	4.94	10.97

TABLE 17.—DIGESTIBILITY OF FROZEN HORSEMEAT—DATA FOR CALCULATION OF THE COEFFICIENTS OF DIGESTIBILITY (COLLECTION PERIOD OF SEVEN DAYS)

	Animal	Original weight of feed or faeces	Nutrients			
			Dry matter	Organic matter	Nitrogen	Ether extract
		gm.	gm.	gm.	gm.	gm.
Period 1—						
In frozen horse-meat (grams)	A	2380	605.7	584.8	86.9	70.7
	B	3220	819.5	791.2	117.5	95.6
	C	1960	498.8	481.6	71.5	58.2
	D	2800	712.6	688.0	102.2	83.2
In faeces (grams)	A	111	33.7	31.3	4.3	1.0
	B	106	31.9	29.3	4.3	1.2
	C	115	33.9	29.8	4.6	1.0
	D	148	40.5	37.4	5.8	1.2
Coefficients, %	A		94.4	94.8	95.1	98.6
	B		96.1	96.3	96.3	98.7
	C		93.2	93.8	93.6	98.3
	D		94.3	94.6	94.3	98.6
Period 2—						
In frozen horse-meat (grams)	A	2800	631.2	602.2	77.1	113.3
	B	2380	524.2	508.8	67.5	96.9
	C	3220	814.2	789.2	103.4	148.3
	D	1960	520.8	520.8	68.2	95.3
In faeces (grams)	A	130	39.7	36.0	4.0	5.4
	B	104	30.0	26.2	3.6	3.7
	C	227	68.4	64.7	7.7	4.4
	D	157	47.4	44.3	5.8	5.8
Coefficients, %	A		93.7	94.0	94.8	95.2
	B		94.3	94.9	94.7	96.2
	C		91.6	91.8	92.6	97.0
	D		91.2	91.5	91.5	93.9
Period 3—						
In frozen horse-meat (grams)	A	2100	590.1	570.4	68.9	104.6
	B	1260	354.1	342.2	41.3	62.7
	C	1820	511.4	494.3	59.7	90.6
	D	1540	432.7	418.3	50.5	76.7
In faeces (grams)	A	157	44.2	40.5	3.8	6.4
	B	51	17.6	16.3	1.7	2.9
	C	113	37.8	34.9	3.4	6.6
	D	137	42.8	39.5	3.2	11.4
Coefficients, %	A		92.5	92.9	94.5	93.9
	B		95.0	95.2	95.9	95.4
	C		92.6	92.9	94.3	92.7
	D		90.1	90.6	93.7	85.1
Period 4—						
In frozen horse-meat (grams)	A	1260	332.8	321.0	43.1	48.6
	B	1820	480.7	463.7	62.2	70.3
	C	1540	406.7	392.4	52.7	59.4
	D	2100	554.6	335.1	71.8	81.1
In faeces (grams)	A	62	23.2	21.0	2.3	3.5
	B	83	23.3	21.7	2.6	2.1
	C	108	26.9	23.8	3.0	2.5
	D	97	33.6	31.8	4.1	1.8
Coefficients, %	A		93.0	93.5	94.7	92.8
	B		95.2	95.3	95.8	97.0
	C		93.4	93.9	94.3	95.8
	D		93.9	94.1	94.3	97.8

TABLE 18—DIGESTIBILITY OF FROZEN BEEF (CHEMICAL COMPOSITION OF THE RATION AS FED)

Period	Dry matter	Organic matter	Nitrogen	Crude protein N × 6.25	Ash	Ether extract
	%	%	%	%	%	%
1	26.99	25.97	3.10	19.38	0.72	6.03
2	28.58	27.63	3.51	21.94	0.95	5.96
3	29.91	29.01	3.31	0.69	0.90	7.44
4	26.28	25.41	3.67	22.94	0.87	3.72

TABLE 19.—DIGESTIBILITY OF FROZEN BEEF—CHEMICAL COMPOSITION OF REJECTED RATIONS

Period animal and amount	Dry matter	Organic matter	Nitrogen	Protein N × 6.25	Ash	Ether extract
	%	%	%	%	%	%
1. Animal C 56 grams	95.75	89.98	14.30	89.38	5.77	15.50
2. Animal D 99 grams	97.05	83.91	10.24	64.00	13.14	22.30
3. Animal D 240 grams	96.96	93.43	10.26	64.13	3.53	27.56
4. Animal D 51 grams	99.69	96.42	13.27	82.94	3.27	11.24

TABLE 20.—DIGESTIBILITY OF FROZEN BEEF—DATA FOR CALCULATION OF COEFFICIENTS OF DIGESTIBILITY (COLLECTION PERIOD OF 7 DAYS)

——	Animal	Original weight of feed or faeces	Nutrients			
			Dry matter	Original matter	Nitrogen	Ether extract
Period 1—		gm.	gm.	gm.	gm.	gm.
in frozen beef	A	1925	513.8	499.9	59.7	116.1
chucks (grams)	B	1575	420.4	409.0	48.8	95.0
	C	2275	553.6	540.4	62.5	128.3
	D	1225	230.9	235.1	27.9	51.8
In faeces (grams)	A	44	14.4	13.0	1.3	1.3
	B	68	18.8	16.7	2.2	2.3
	C	58	22.0	19.7	2.0	2.2
	D	21	9.5	8.5	0.9	1.0
Coefficients, %	A		97.2	97.2	97.8	98.9
	B		95.5	95.9	95.5	97.6
	C		96.0	96.4	96.8	98.3
	D		95.9	96.4	96.8	98.1
Period 2—	A	2275	650.2	628.6	79.9	135.6
In frozen beef	B	1225	350.1	338.5	43.0	73.0
chucks (grams)	C	1925	550.2	531.9	67.6	114.7
	D	1575	450.1	435.2	55.3	93.9
In faeces (grams)	A	52	18.6	15.9	1.6	1.5
	B	57	17.3	15.4	1.7	1.5
	C	48	18.9	16.8	1.9	1.5
	D	44	17.8	15.7	1.3	1.9
Coefficients, %	A		97.1	97.5	98.0	98.9
	B		95.1	95.5	96.0	97.9
	C		96.6	96.8	97.2	98.7
	D		96.0	96.4	97.6	98.0
Period 3—	A	1225	366.4	355.4	40.5	91.1
In frozen beef	B	1925	575.8	558.4	63.7	143.2
chucks (grams)	C	1575	471.1	456.9	52.1	117.2
	D	2275	447.8	435.8	50.7	103.1
In faeces (grams)	A	14	5.9	5.2	0.7	1.6
	B	127	27.0	24.3	2.4	2.7
	C	49	17.7	15.7	1.8	1.7
	D	114	21.9	19.6	2.3	2.3
Coefficients, %	A		98.4	98.5	98.3	99.3
	B		95.3	95.6	96.2	98.1
	C		96.2	96.6	96.5	98.5
	D		95.1	95.5	95.5	97.7
Period 4—	A	1575	413.9	400.2	57.8	58.6
In frozen beef	B	2275	597.9	578.1	83.5	84.6
chucks (grams)	C	1225	231.9	311.3	45.0	45.6
	D	1925	455.9	439.9	63.8	65.9
In faeces (grams)	A	37	16.7	15.0	1.6	1.4
	B	75	25.3	22.8	2.4	2.9
	C	26	13.2	11.8	1.5	1.0
	D	63	18.1	16.8	2.1	1.6
Coefficients, %	A		96.0	96.3	97.2	97.6
	B		95.8	96.1	97.1	96.6
	C		95.9	96.2	96.7	97.8
	D		96.0	96.2	96.7	97.6

DIGESTIBILITY STUDIES WITH FOXES

II. DIGESTIBILITY OF FROZEN BEEF TRIPE, FROZEN LIP MEAT, FROZEN BEEF HEARTS AND FROZEN COW UDDERS[1]

W. R. INMAN[2]

Experimental Fox Ranch, Summerside, P. E. I.

[Received for publication April 19, 1941]

In a previous paper (1) it was shown that foxes effected a better utilization of fresh beef and frozen beef than they did of frozen horsemeat, for the dry matter, organic matter, nitrogen and ether extract. This communication reports a comparison of the digestibilities of frozen beef tripe, frozen lip meat, frozen beef hearts and frozen cow udders. These, with the exception of the last named, are widely used in the fox-farming industry. Cow udders have not enjoyed the same popularity, largely because of their essentially fatty nature. The price is low, however, and they should be valuable as an adjuvant to the leaner meats, e.g., horsemeat. Such an array of meats is interesting also, because it includes products representing the three types of muscle meat in the animal body, striated, cardiac, and smooth.

EXPERIMENTAL

The 4 pedigreed male silver foxes were born and raised at the Dominion Experimental Fox Ranch, Summerside. All were approximately the same age, 16 months.

The methods of preparing, sampling and preserving rations and faeces will be found elsewhere (1). The tripe, however, instead of being ground, was fed in chunks. Grinding seemed to reduce the tripe to a gelatinous consistency which made handling very difficult. Furthermore, it apparently thawed completely during the grinding and subsequent weighing and sampling. As this experiment was conducted during the summer and autumn it was thought advisable to avoid this thawing as decomposition begins very readily in tripe. Therefore, the following procedure was adopted: the frozen block of tripe was first thoroughly sampled by means of a $\frac{3}{4}$ in. cork borer. The borings, about 3 inches long and numbering 16 to 20, were used to determine the chemical composition. From the remainder of the block chunks were cut and trimmed to exactly 400 grams, wrapped in heavy waxed paper and maintained frozen until fed.

The quantity of the ration was based upon the amount the animals would consume consistently. The levels were 400 grams per day for tripe, 300 grams for hearts and 150 grams for the cow udders. The lip meat was fed at 300 grams in periods 1, 3, 4, and 5, and 200 grams in period 2. As it had been demonstrated that the plane of nutrition did not affect the digestibility of frozen beef between the limits of 175 to 325 grammes per day (1) the coefficients for this period were accepted without modification. No feed was rejected during the experiment.

[1] Contribution from the Animal Husbandry Division, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Agricultural Assistant.

There were 5 periods of which 2, 3, 4, and 5, constitute a 4 × 4 latin square. The periods consisted of a 3-day preliminary and a 10-day collection. The experimental data will be found in Tables 6 and 7 of the Appendix. The schedule of the digestion trials is presented in Table 1.

TABLE 1.—SCHEDULE OF DIGESTION TRIALS

Period	Collection, 1937	Animals			
		A	B	C	D
1	July 3 – July 12	Beef tripe	Lip meat	Beef hearts	Cow udders
2	July 31 – Aug. 9	Beef hearts	Cow udders	Lip meat	Beef tripe
3	Aug. 28 – Sept. 6	Lip meat	Beef hearts	Beef tripe	Cow udders
4	Oct. 16 – Oct. 25	Cow udders	Beef tripe	Beef hearts	Lip meat
5	Nov. 13 – Nov. 22	Beef tripe	Lip meat	Cow udders	Beef hearts

TABLE 2.—COEFFICIENTS OF DIGESTIBILITY ARRANGED BY RATIONS AND PERIODS*

Nutrients	Periods	Coefficients of digestibility in per cent				
		Frozen beef tripe	Frozen lip meat	Frozen beef hearts	Frozen cow udders	Means
Dry matter	1	92.7 (A)	96.0 (B)	92.7 (C)	91.1 (D)	93.1
	2	**93.6 (D)**	**96.2 (C)**	**96.7 (A)**	**92.8 (B)**	**94.8**
	3	**95.1 (C)**	**96.9 (A)**	**95.7 (B)**	**95.1 (D)**	**95.7**
	4	**90.6 (B)**	**96.2 (D)**	**96.1 (C)**	**95.3 (A)**	**94.6**
	5	**92.4 (A)**	**96.8 (B)**	**95.2 (D)**	**95.3 (C)**	**94.8**
Mean all Periods		93.3	96.4	95.3	93.8	94.6
Mean 4 × 4 square		92.9	96.5	95.9	94.6	95.0
Organic matter	1	94.1 (A)	96.3 (B)	93.2 (C)	92.3 (D)	94.0
	2	**94.1 (D)**	**96.6 (C)**	**97.0 (A)**	**94.0 (B)**	**95.4**
	3	**95.6 (C)**	**97.1 (A)**	**96.1 (B)**	**95.5 (D)**	**96.1**
	4	**92.6 (B)**	**96.7 (D)**	**96.5 (C)**	**95.7 (A)**	**95.4**
	5	**93.7 (A)**	**97.0 (B)**	**95.6 (D)**	**95.7 (C)**	**95.5**
Mean all Periods		94.0	96.7	95.7	94.6	95.3
Mean 4 × 4 square		94.0	96.9	96.3	95.2	95.6
Nitrogen	1	94.6 (A)	95.6 (B)	95.5 (C)	92.0 (D)	94.4
	2	**95.4 (D)**	**95.7 (C)**	**95.0 (A)**	**89.2 (B)**	**93.8**
	3	**95.5 (C)**	**96.7 (A)**	**95.7 (B)**	**90.9 (D)**	**94.7**
	4	**95.3 (B)**	**96.1 (D)**	**96.1 (C)**	**94.4 (A)**	**95.5**
	5	**96.1 (A)**	**96.5 (B)**	**94.6 (D)**	**93.2 (C)**	**95.1**
Mean all Periods		95.4	96.1	95.4	91.9	94.7
Mean 4 × 4 square		95.6	96.2	95.4	91.4	94.8
Ether extract	1	98.1 (A)	98.7 (B)	95.8 (C)	97.8 (D)	97.6
	2	**95.3 (D)**	**99.0 (C)**	**98.7 (A)**	**98.9 (B)**	**98.0**
	3	**96.6 (C)**	**99.0 (A)**	**98.4 (B)**	**98.6 (D)**	**98.2**
	4	**97.8 (B)**	**99.1 (D)**	**98.6 (C)**	**97.8 (A)**	**98.6**
	5	**97.7 (A)**	**98.0 (B)**	**98.0 (D)**	**98.2 (C)**	**98.0**
Mean all Periods		97.1	98.8	97.9	98.3	98.1
Mean 4 × 4 square		96.9	98 8	98.4	98.4	98.2

*4 × 4 Latin square indicated by boldface type. Animals represented by capital letters.

TABLE 3.—ANALYSIS OF VARIANCE FOR THE DATA AS ARRANGED BY RATIONS

	Variance due to	Variance	$\frac{1}{2}$ Log$_e$ variance	Z	Necessary differences
Dry matter	Ration	11.99	1.2420	0.8432	1.98
	Error	2.22	0.3988		
Organic matter	Ration	7.15	0.9836	0.8083	1.59
	Error	1.42	0.1753		
Nitrogen	Ration	17.31	1.4276	1.2733	1.56
	Error	1.36	0.1537		
Ether extract	Ration	2.44	0.4460	1.3320	0.91
	Error	0.17	−0.8860		

Degrees of Freedom from Ration = 3; Degrees of Freedom from Error = 16.
Z for P. at 0.05 = 0.5876; Z for P. at 0.01 = 0.8331.

RESULTS

In Table 2 all the coefficients are collected and arranged by periods and rations (the animals are designated by capitals). In Table 3, which considers all periods, the variance due to the ration is compared with that due to error and the differences necessary for significance at the 5% point are given. It will be seen from these tables that for the dry matter, frozen lip meat is superior to both tripe and udders, and hearts are better utilized than tripe; for the organic matter the same is true. In the nitrogen the udders are lower than the other three, among which no significant difference occurred. In the case of the ether extract tripe is lower than the other three, the difference between lip meat and hearts is borderline, and while statistically significant, depends on the one low value for hearts in Period I and is better disregarded.

The means of the animals for the 4 × 4 square will be found in Table 4 and the analysis of the variance in the 4 × 4 square in Table 5, which includes the necessary differences at the 5% point.

TABLE 4.—ANIMAL MEANS (4 × 4 LATIN SQUARE)

Animal	Dry matter	Organic matter	Nitrogen	Ether extract
A	95.3	95.9	95.6	98.5
B	94.0	94.9	94.2	98.3
C	95.4	96.1	95.1	98.1
D	95.0	95.5	94.3	97.8

From Table 5 it will be seen that the animals and periods accounted for quite small fractions of the variance, in no cases having significant effects.

Considering the necessary differences in Table 5 with the means for the 4 × 4 square in Table 2, the following should be noted: for the dry matter, nitrogen and ether extract the results are the same as those deduced from a consideration of all periods. In the organic matter, however, the difference between the lip meat and cow udders is no longer significant. There are two reasons for this. In the first place the mean udder value for all periods is lowered by the result of the first period. In the second the necessary differences are greater in the 4 × 4 square; these in turn are

TABLE 5.—ANALYSIS OF THE VARIANCE (4 × 4 LATIN SQUARE)

Nutrients	Variance due to	D.F.	Sums of squares	Variance	½ Log$_e$ var.	Z	Necessary differences
Dry matter	Ration	3	30.51	10.17	1.2269	1.1074	1.94
	Animal	3	6.45	2.15	0.3827	0.2632	
	Period	3	2.92	0.97	*		
	Error	6	7.60	1.27	0.1195		
	Total	15	47.48				
Organic matter	Ration	3	19.01	6.34	0.9235	0.8536	1.31
	Animal	3	3.18	1.06	*		
	Period	3	1.26	0.42	*		
	Error	6	3.44	0.57	0.0699		
	Total	15	26.89				
Nitrogen	Ration	3	45.07	15.02	1.3547	1.2677	1.90
	Animal	3	5.43	1.81	0.2966	0.2096	
	Period	3	6.01	2.00	0.3466	0.2596	
	Error	6	7.14	1.19	0.0870		
	Total	15	63.65				
Ether extract	Ration	3	9.43	3.14	0.5721	0.8711	1.28
	Animal	3	1.27	0.42	*		
	Period	3	0.88	0.29	*		
	Error	6	3.30	0.55	−0.2990		
	Total	15	14.88				

For $N_1 = 3$ and $N_2 = 6$.
$Z = 0.7798$ at $P.$ of 0.05; $Z = 1.1401$ at $P.$ of 0.01.
* Variance less than that due to error.

based on the error variance which is relatively larger in the 4 × 4 square due to the fact that the degrees of freedom for animals and periods account for quite small portions of the total variance.

A point of particular interest is the comparatively low apparent digestibility of the nitrogen of the cow udders. There are two possible explanations of this. In the first place the nitrogen intake was at a very

low level, the average daily intakes for the 5 periods being 3.25, 2.03, 2.30, 3.38, and 3.23 grams. The corresponding digestion coefficients were 92.0, 89.2, 90.9, 94.4, and 93.2 respectively. It may be then that at the lower nitrogen feeding levels the alimentary contribution to the faecal nitrogen was a modifying factor. Examination of the experimental data in Tables 6 and 7 will reveal that the nitrogen intakes for the other meats varied from 5.40 grams to 9.67 grams per day. Furthermore, while the dry matter of the udders contained only 5.56 ± 0.67% nitrogen, the respective values for tripe, lip meat and hearts were 9.64 ± 0.33, 8.53 ± 0.21 and 8.00 ± 0.98. Secondly, consider the anatomy of the udder; fibrous and fibro-elastic tissue are very much in evidence. It has been shown (2, 3, 4) that the nitrogen of such tissues is not as well utilized as that from muscle.

SUMMARY

The digestibilities of frozen beef tripe, frozen lip meat, frozen beef hearts and frozen cow udders have been compared as feed for silver foxes.

1. To consider the results by nutrients:—

Dry Matter: The lip meat was better utilized than the tripe or udders; there was a statistically significant difference between the hearts and tripe in favour of the hearts.

Organic Matter: The lip meat and hearts showed higher mean coefficients than the tripe. The udders did not differ significantly from any of the other meats.

Nitrogen: The average value for udders was lower than for the other three meats, among which there was no difference.

Ether Extract: The mean value for tripe was lower than for the other three meats among which there was no difference.

2. There were no significant variances due to animals or periods.

ACKNOWLEDGMENT

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APPENDIX

TABLE 6.—CHEMICAL COMPOSITION OF THE RATIONS

Period, animal and ration	Dry matter	Organic matter	Nitrogen	Protein (N × 6.25)	Ash	Ether extract
	%	%	%	%	%	%
1. A. Tripe	24.98	24.02	2.38	14.88	0.96	8.08
B. Lip meat	33.54	32.92	2.72	17.00	0.62	16.65
C. Hearts	23.87	23.02	2.81	17.56	0.85	5.88
D. Cows' udders	33.96	32.72	2.15	13.43	1.24	19.98
2. D. Tripe	20.66	19.72	2.08	13.00	0.94	4.65
C. Lip meat	31.26	30.60	2.70	16.88	0.66	13.57
A. Hearts	32.92	31.89	2.07	12.94	1.03	12.33
B. Cows' udders	35.89	34.29	1.35	8.44	1.60	22.68
3. C. Tripe	25.52	24.75	2.44	15.25	0.77	7.15
A. Lip meat	31.27	30.64	2.76	17.25	0.63	13.25
B. Hearts	31.53	30.61	2.35	14.69	0.92	11.28
D. Cows' udders	36.70	35.97	1.53	9.56	0.73	22.28
4. B. Tripe	23.06	21.58	1.97	12.31	1.48	7.98
D. Lip meat	32.30	31.62	2.57	16.06	0.68	15.42
C. Hearts	29.69	28.81	2.29	14.31	0.88	13.53
D. Cows' udders	31.19	30.36	2.25	14.06	0.83	16.45
5. A. Tripe	21.85	20.70	2.29	14.31	1.15	5.43
B. Lip meat	25.39	24.67	2.31	14.44	0.72	6.54
D. Hearts	31.21	30.35	2.11	13.19	0.86	15.28
C. Cows' udders	33.98	33.11	2.15	13.43	0.87	18.04

TABLE 7.—CALCULATION OF THE COEFFICIENTS OF DIGESTIBILITY

PERIOD 1

Animal and ration	Original weight (in grams) feed or faeces	Nutrients in grams			
		Dry matter	Organic matter	Nitrogen	Ether extract
A. Tripe	4000	999.2	960.8	95.2	323.2
B. Lip meat	3000	1006.2	987.6	81.6	499.5
C. B. Hearts	3000	716.1	690.6	84.3	176.4
D. Cows' udders	1500	509.4	490.8	32.3	299.7
Faeces A.	198	73.3	56.6	5.1	6.3
B.	89	40.2	36.9	3.6	6.5
C.	110	52.0	46.7	3.8	7.4
D.	78	45.4	37.9	2.6	6.5
Coefficients in per cent		92.7	94.1	94.6	98.1
		96.0	96.3	95.6	98.7
		92.7	93.2	95.5	95.8
		91.1	92.3	92.0	97.8

PERIOD 2

A. B. Hearts	3000	987.6	956.7	62.1	369.9
B. Cows' udders	1500	539.7	514.4	20.3	340.2
C. Lip meat	2000	625.2	618.0	54.0	271.4
D. Tripe	4000	826.4	788.8	83.2	186.0

TABLE 7.—CALCULATION OF THE COEFFICIENTS OF DIGESTIBILITY—*Concluded*

PERIOD 2—*Concluded*

Animal and ration	Original weight (in grams) feed or faeces	Nutrients in grams			
		Dry matter	Organic matter	Nitrogen	Ether extract
Faeces A.	108	32.6	29.0	3.1	4.7
B.	58	39.0	31.0	2.2	3.8
C.	66	23.8	21.1	2.3	2.7
D.	125	52.6	46.2	3.8	8.7
Coefficients in per cent		96.7	97.0	95.0	98.7
		92.8	94.0	89.2	98.9
		96.2	96.6	95.7	99.0
		93.6	94.1	95.4	95.3
PERIOD 3					
A. Lip meat	3000	938.1	919.2	82.8	397.5
B. B. Hearts	3000	941.1	918.3	70.5	338.4
C. Tripe	4000	1020.8	990.0	97.6	286.0
D. Cows' udders	1500	550.5	539.6	23.0	334.2
Faeces A.	84	29.2	26.7	2.7	4.1
B.	77	40.0	35.6	3.0	5.5
C.	151	50.4	43.9	3.4	9.7
D.	47	26.9	24.5	2.1	4.8
Coefficients in per cent		96.9	97.1	96.7	99.0
		95.7	96.1	95.7	98.4
		95.1	95.6	95.5	96.6
		95.1	95.5	90.9	98.6
PERIOD 4					
A. Cows' udders	1500	467.9	455.4	33.8	246.8
B. Tripe	4000	922.4	863.2	91.6	319.2
C. B. Hearts	3000	890.7	864.3	68.7	400.5
D. Lip meat	3000	969.0	948.6	77.1	462.6
Faeces A.	77	22.0	19.8	1.9	5.5
B.	168	86.5	64.0	3.7	6.9
C.	104	34.3	30.5	2.7	5.6
D.	104	36.5	31.2	3.0	4.3
Coefficients in per cent		95.3	95.7	94.4	97.8
		90.6	92.6	95.3	97.8
		96.1	96.5	96.1	98.6
		96.2	96.7	96.1	99.1
PERIOD 5					
A. Tripe	4000	974.0	828.0	91.6	217.2
B. Lip meat	3000	761.7	740.1	69.3	196.2
C. Cows' udders	1500	509.7	496.7	32.3	270.6
D. B. Hearts	3000	936.3	907.5	63.3	458.4
Faeces A.	198	66.4	52.3	3.6	5.0
B.	64	24.7	22.5	2.4	3.9
C.	65	23.8	21.6	2.2	5.0
D.	211	44.5	39.9	4.2	9.2
Coefficients in per cent		92.4	93.7	96.1	97.7
		96.8	97.0	96.5	98.0
		95.3	95.7	93.2	98.2
		95.2	95.6	94.6	98.0

THE EFFECT OF STEM RUST ON THE YIELD, QUALITY, CHEMICAL COMPOSITION, AND MILLING AND BAKING PROPERTIES OF MARQUIS WHEAT[1]

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INTRODUCTION

Numerous studies have been made to determine the effect of stem rust (*Puccinia graminis Tritici* Erikss. & Henn.) and leaf rust (*Puccinia triticina* Erikss.) on the yield of wheat. Hayes *et al.* (15), Mains (21), Johnston (17), Caldwell *et al.* (4) and Waldron (31) in the United States, Greaney (11) and Peturson and Newton (27) in Canada, Neill (24) in New Zealand, Phipps (26) in Australia, and others, have shown that stem rust and leaf rust cause very appreciable reductions in the yield of wheat. An examination of the literature, however, reveals that relatively few studies have been made to determine the effects of rust, particularly stem rust, on the chemical composition of the wheat grain and straw, and on the milling and baking properties of the grain.

Certain chemical analyses of rusted and rust-free wheat, both grain and straw, were made by Shutt (28), and by Snyder (29), in 1904. Both of these workers concluded that rust, undoubtedly stem rust, markedly affected the chemical composition of the grain and straw of wheat. Later, Ince (16), Headden (13), and Mangels and Sanderson (20) showed that stem rust (*P. graminis Tritici*) is a very important factor affecting the chemical composition of wheat plants. Recently, Caldwell *et al.* (4) made a detailed study of the effect of leaf rust (*P. triticina*) on the composition of the plants and grain of certain winter wheats, and Murphy (22) has investigated the effect of crown rust (*Puccinia coronata* Erikss.) on the composition of oat plants and grain. It would appear that no detailed study of the influence of stem rust on the chemical composition of the grain and straw of wheat, especially hard red spring wheat, has been attempted.

The relation of stem rust to the milling and baking properties of hard red spring wheat is one phase of the rust problem requiring further investigation. The information that is available concerning this subject is scattered through a large volume of literature and much of it is incidental to the consideration of other effects resulting from stem rust infection. More exact information concerning the effect of leaf rust (*P. triticina*) on the milling and baking properties of susceptible and resistant wheat varieties has, however, been recently obtained by Peturson and Newton (27) in Canada, and by Phipps (26) in Australia.

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[1] Contribution No. 660, Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada. A joint contribution from the Division of Botany and Plant Pathology and the Division of Chemistry, Science Service, and the Cereal Division, Experimental Farms Service, Department of Agriculture, Ottawa, Canada.

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The present studies were undertaken to obtain more definite information concerning the effect of stem rust (*P. graminis Tritici*) on the chemical composition and milling and baking properties of hard red spring wheat. As the investigation required the growing of a large number of rusted and non-rusted wheat plots, an opportunity was afforded to study in considerable detail the effect of rust on the yield, kernel weight, bushel weight, and commercial grade. The investigation was commenced in 1933 and continued until 1937, and was carried out as a co-operative project by the Division of Botany and Plant Pathology, and Division of Chemistry, Science Service, and the Cereal Division, Experimental Farms Service, of the Dominion Department of Agriculture, Ottawa, Canada.

DESIGN OF FIELD EXPERIMENTS, METHODS, AND MATERIALS

Marquis, a standard variety of hard red spring wheat, susceptible to stem rust and moderately susceptible to leaf rust, was used throughout the investigation. About an acre of Marquis was sown each year on summer-fallowed soil in accordance with normal farm practice. On it, after the wheat plants had emerged, a 10 × 10 Latin Square with long, narrow 1/400-acre plots (27.2 ft. × 4 ft. plus borders) was cut out. Paths and buffer strips 5 ft. in width separated the plots, the buffer strips serving as a screen against the drift of dust from one plot to another.

To secure a wide range of rust infection on different series of plots, 10 different treatments with sulphur dust were used. These treatments were randomized in the 10 × 10 Latin Square. A plan of a typical plot experiment, and the sulphur-dusting treatments used to vary the intensity of rust infection on different series of replicated plots in each experiment, are given in Table 1.

In Table 1, Treatment J, the untreated check, permitted normal rust infection, while Treatment I, the heaviest sulphur treatment, was designed to give complete control of rust. Treatments A to H were designed to give a range in degrees of infection from almost normal infection to almost complete rust control. The plot technique and the sulphur dusting schedules employed in the present investigation were similar to those used by Greaney (11) in field experiments on the control of rust by sulphur dusting.

Kolodust, a finely-divided sulphur dust, was used throughout the experiments. Each year, initial applications of Kolodust were made to the growing plants during the first week of July. Thereafter, series of plots were dusted at different rates and time-intervals, until the wheat plants were practically mature.

During the latter part of June the plots were artificially inoculated with stem rust. Thus, each year, the wheat was grown under conditions of artificially induced epidemics of stem rust in conjunction with naturally occurring ones. The plots were not artificially inoculated with leaf rust, but were subject to naturally occurring infections of this disease.

Stem rust percentages were estimated just before the plants ripened; leaf rust percentages, while the leaves were still green. The estimate of rust percentages was based on the scale of stem-rust percentages adopted by the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture.

TABLE 1.—PLAN OF FIELD EXPERIMENT, AND METHODS USED TO TREAT SERIES OF PLOTS OF MARQUIS WHEAT WITH SULPHUR DUST TO OBTAIN DIFFERENT DEGREES OF SEVERITY OF STEM RUST INFECTION ON A SINGLE STANDARD VARIETY

PLAN OF FIELD EXPERIMENT

(Experiment of 1937)

	I	II	III	IV	V	VI	VII	VIII	IX	X
I	15 B	80 F	90 J	7 E	20 H	5 I	60 G	35 D	55 C	55 A
II	96 J	70 G	7 I	15 B	70 F	35 D	55 A	30 H	10 E	50 C
III	60 C	35 D	50 A	20 H	5 I	15 B	70 F	60 G	90 J	12 E
IV	45 A	15 B	10 E	54 C	90 J	65 F	30 D	4 I	20 H	65 G
V	20 H	10 E	60 F	3 I	35 D	60 G	90 J	55 C	55 A	20 B
VI	6 I	45 A	55 G	70 F	15 B	50 C	10 E	85 J	35 D	30 H
VII	80 F	3 I	20 H	30 D	55 G	5 E	50 C	55 A	20 B	90 J
VIII	12 E	90 J	30 D	50 A	60 C	18 H	20 B	80 F	60 G	5 I
IX	35 D	55 C	25 B	60 G	50 A	90 J	15 H	10 E	7 I	85 F
X	65 G	30 H	55 C	90 J	15 E	50 A	7 I	20 B	85 F	35 D

System of replication: 10 × 10 Latin Square.
Area of each plot: 1/400-acre (27.2 ft. × 4 ft.) with borders (28 ft. × 5 ft.).
Buffer plots and paths: 5 ft. between plots.
Letters = treatment symbols. Figures = stem rust percentages.

KEY TO SULPHUR DUSTING TREATMENTS

(Experiments of 1934, 1935 and 1937)

Amount of sulphur dust per application per acre, lb.	Treatment symbol									
	A	B	C	D	E	F	G	H	I	J
	Interval between dust applications in days									
	5	2	10	5	2	15	10	5	2	–
0										x
15	x	x								
30			x	x	x					
45						x	x	x	x	

Yield, 1,000-kernel weight, and weight per measured bushel, were taken for individual plots of each experiment. Yield data were obtained by harvesting and threshing each 1/400-acre plot separately after the border rows had been removed. The mean weight of 4 random samples of 250 kernels each was used to compute the 1,000-kernel weight for each plot, and the weight per measured bushel determinations for individual plots was ascertained by weighing the grain according to Canadian Grain Standards. The commercial grade of the composite samples of grain of each experiment was determined by officials of the Western Grain Inspection Division, Winnipeg, Manitoba.

Samples of grain from individual plots of the experiments of 1934, 1935, and 1937 were analyzed for protein, phosphorus, calcium, and ash content. Straw samples from each plot of the 1937 experiment were similarly analyzed. All chemical studies of the investigation were made at the laboratory of the Division of Chemistry, Science Service, Ottawa.

Composite grain samples were obtained for milling and baking tests from each series of dusted and non-dusted plots of Marquis wheat in 1934, 1935, and 1937. These samples (10 lb.) were secured by compositing 1-pound lots from the 10 plots of similar treatment in each experiment. Samples of these composite lots were milled and baked in the experimental milling and baking laboratory of the Cereal Division, Experimental Farms Service, Ottawa.

Detailed experimental methods pertaining to the chemical and milling and baking studies are given in later parts of this paper.

Newton and Malloch (23) directed attention to the variation in the quality of wheat grown in replicated plots, and to the need of special precaution in sampling for quality tests. In the present work, therefore, the field experiments were designed so that the significance of small differences in grain quality and yield between plots could be tested statistically. All data on rust, yield, kernel weight, and bushel weight, and a large part of the chemical and milling and baking data, were subjected to statistical analysis. All statistical analyses carried out in this investigation follow the methods described by Goulden (9) and Snedecor (30).

The results of the investigation are presented in three parts as follows:

I. Rust infection in relation to grain yield and quality.

II. Effect of rust on the chemical composition of grain and straw.

III. Effect of rust on the milling and baking qualities of Marquis wheat.

The work carried out at the Dominion Laboratory of Plant Pathology, Winnipeg, is presented in Part I. The laboratory of the Division of Chemistry, Ottawa, reports the results of the chemical analyses of grain and straw in Part II, and the results of the milling and baking tests are reported by the Cereal Division, Ottawa, in Part III.

EXPERIMENTAL RESULTS

I. Rust Infection in Relation to Grain Yield and Quality

Severity of Rust Infection in Experimental Years

During the 5-year period, 1933–37, severe infections of stem rust *(P. graminis Tritici)* occurred in the experimental Marquis plots at Winnipeg in 1935 and 1937, and moderately heavy infections in 1934, while

stem rust was of relatively little importance in 1933 and 1936. Leaf rust *(P. triticina)* did not develop to any extent in the plots of 1933, 1936, and 1937, but was a factor of considerable importance in 1934 and 1935.

Unfavourable weather conditions in June and early July, and the early ripening of the crop were the factors chiefly responsible for the limited development of rust in 1933 and 1936. The extent to which stem rust developed in various series of dusted and undusted Marquis plots in these years is indicated in Table 2.

TABLE 2.—THE EFFECT OF VARIOUS SULPHUR-DUSTING TREATMENTS ON THE DEVELOPMENT OF STEM RUST IN 1933 AND 1936, AND THE INFLUENCE OF STEM-RUST INFECTION ON KERNEL WEIGHT, TEST WEIGHT PER BUSHEL, YIELD, AND COMMERCIAL GRADE OF MARQUIS WHEAT GROWN AT WINNIPEG IN 1933 AND 1936

(Data are means of 10 plots)

Plot series	Sulphur dust application*			Severity of stem rust infection	Yield and quality of grain			
	Amount of sulphur per acre	Interval between dustings	Total number of dustings		Weight of 1,000 kernels	Test weight per bushel	Yield per acre	Commercial grade (Manitoba Northern)
	lb.	days		%	gm.	lb.	bu.	
Experiment of 1933								
I	45	2	12	1	32.0	65	14.6	1
E	30	2	12	1	32.8	66	15.7	1
B	15	2	12	2	32.7	65	14.3	1
H	45	5	6	1	31.9	65	15.2	1
D	30	5	6	2	31.6	65	15.0	1
A	15	5	6	1	32.4	65	15.8	1
G	45	10	3	2	32.0	65	14.8	1
C	30	10	3	2	31.7	65	14.8	1
F	45	15	2	1	32.3	65	15.4	1
J	0	—	0	4	32.4	65	15.5	1
Experiment of 1936								
I	45	2	18	1	29.6	62	21.1	2
E	30	2	18	1	29.4	62	21.2	2
B	15	2	18	5	30.0	62	20.9	2
H	45	5	8	2	29.6	61	21.7	2
D	30	5	8	5	29.0	61	20.2	2
A	15	5	8	5	28.9	62	20.9	2
G	45	10	4	2	29.3	62	21.0	2
C	30	10	4	5	29.5	62	20.5	2
F	45	15	3	5	29.1	62	20.4	2
J	0	—	0	10	29.3	61	20.1	2

* Period of dusting: 1933, July 10 – Aug. 4; 1936, July 2 – Aug. 8.

A wide range in stem rust infection was obtained on different series of plots in 1934 and 1935. In both years leaf rust was a complicating factor of considerable importance, although more so in 1935 than in 1934. However, owing to the fact that Marquis wheat is only moderately susceptible to leaf rust, there is little question but that by far the greater portion of the rust damage in these years was attributable to stem rust. The leaf and stem rust severities obtained on the ten different series of Marquis plots in 1934 and 1935 are given in Table 3.

TABLE 3.—THE INFLUENCE OF RATE AND FREQUENCY OF SULPHUR DUST APPLICATION ON THE SEVERITY OF STEM RUST AND LEAF RUST INFECTION ON MARQUIS WHEAT IN 1934, 1935, AND 1937

(Data are means of 10 plots)

Plot series	Sulphur dust application*			Severity of rust infection					
	Rate of sulphur per acre	Interval between dustings	Total number of dustings†	1934		1935		1937	
				Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust
	lb.	days		%	%	%	%	%	%
I	45	2	24	2	4	3	6	5	Tr.
E	30	2	24	5	4	6	9	10	Tr.
B	15	2	24	8	8	12	15	18	1
H	45	5	10	10	10	59	48	22	2
D	30	5	10	12	11	65	66	34	3
A	15	5	10	20	16	71	68	51	4
G	45	10	5	20	20	72	74	55	2
C	30	10	5	25	23	74	71	61	4
F	45	15	4	29	25	80	75	75	4
J	0	—	0	61	43	88	77	90	5
Necessary difference, 5% level				4.0	11.1	9.6	11.7	3.7	—

* Period of dusting: 1934, July 2 – Aug. 18; 1935, July 4 – Aug. 24; 1937, July 4 – Aug. 23.
† Total number of dustings per plot series in 1934. The number of dustings each plot series received in 1935 and 1937 was essentially similar to that of 1934.

In 1937, the epidemic of stem rust was moderately late in developing and was somewhat less severe than in 1935 at Winnipeg, a condition which lent itself to obtaining a well-graduated series of rust intensities. The average percentages of stem rust for the ten 1/400-acre plot series of Marquis in that year were as follows: 5, 10, 18, 22, 34, 51, 55, 61, 75, and 90%, respectively (Table 3), thus providing highly satisfactory material (grain and straw) for determining the influence of stem rust on the chemical composition, and on the milling and baking properties of a hard red spring wheat.

Effect of Rust on Yield, Kernel Weight, Bushel Weight and Commercial Grade

Results for 1933 and 1936

The complete yield, kernel weight, bushel weight, and commercial grade data of the 1933 and 1936 experiments are given in Table 2.

From the summarized results in Table 2 it is evident that none of the stem rust severities obtained in 1933 and 1936 had any significant effect on yield, kernel weight, bushel weight, and commercial grade of Marquis wheat. In consequence, the field experiments of 1933 and 1936 did not provide suitable material for carrying out tests to determine the effect of rust on the chemical composition and milling and baking properties of Marquis wheat. As, however, the 10 different series of plots of each experiment gave essentially similar yield and grain-quality results, it is evident that the system of plot arrangement used throughout the investigation (10 × 10 Latin Square) was highly efficient in eliminating the possible effects of soil heterogeneity, a factor which Newton and Malloch (23) found of importance in studies on grain quality.

TABLE 4.—THE EFFECT OF STEM-RUST AND LEAF-RUST INFECTION IN DIFFERENT DEGREES OF SEVERITY ON KERNEL WEIGHT, TEST WEIGHT PER BUSHEL, YIELD, AND COMMERCIAL GRADE OF MARQUIS WHEAT IN 1934, 1935, AND 1937

(Data are means of 10 plots)

Plot series	Stem rust	Leaf rust	Weight of 1,000 kernels	Test weight per bushel	Yield per acre	Commercial grade* (Manitoba Northern)
	%	%	gm.	lb.	bu.	
Experiment of 1934						
I	2	4	31.0	64.9	33.4	2
E	5	4	30.0	64.9	31.4	2
B	8	8	29.7	64.9	31.3	2
H	10	10	29.5	64.8	29.6	2
D	12	11	29.5	64.4	28.7	2
A	20	16	28.0	63.9	27.8	2
G	20	20	27.8	64.0	26.3	2
C	25	23	27.5	63.2	24.9	2
F	29	25	27.2	63.5	25.3	3
J	61	43	26.3	60.9	19.8	3
Necessary difference†	4.0	11.1	1.4	0.6	2.5	—
Experiment of 1935						
I	3	6	32.4	63.3	22.0	3
E	6	9	32.2	63.1	21.6	3
B	12	15	32.2	63.0	21.2	3
H	59	48	26.4	60.8	16.3	3
D	65	66	25.5	58.7	14.5	3
A	71	68	24.2	58.2	12.8	3
G	72	74	22.8	56.4	12.6	3
C	74	71	22.7	56.2	12.3	3
F	80	75	18.7	52.7	10.0	4 (Sp.)
J	88	77	16.4	49.9	4.7	6 (Sp.)
Necessary difference†	9.6	11.7	1·4	2.1	2.9	—
Experiment of 1937						
I	5	Tr.	27.8	64.0	23.8	1 (Hd.)
E	10	Tr.	26.9	63.5	20.1	1
B	18	1	23.6	62.0	19.0	2
H	22	2	22.5	61.5	17.5	2
D	34	3	20.3	60.0	15.9	3
A	51	4	17.6	56.0	13.3	4
G	55	2	15.3	53.0	11.2	5 (Sp.)
C	61	4	14.2	51.5	9.6	6 (Sp.)
F	75	4	11.8	44.0	7.0	Feed
J	90	5	9.7	40.0	3.6	Feed
Necessary difference†	3.7	—	1.2	2.7	1.7	—

* Hd. = Manitoba No. 1 Hard. Sp. = Special.
† Necessary difference, 5% level of significance, between plot series.

The results obtained in 1933 and 1936 confirm findings previously reported by one of the writers (11) that, in the absence of rust and other leaf and stem diseases, the dusting of wheat plants with sulphur during the growing period had no appreciable effect on yield, kernel weight, bushel weight and grade. The differences, therefore, observed in yield and grade between different series of dusted and undusted plots in the rust years of 1934, 1935, and 1937, can be attributed to differences in the amount of rust on the plants and not to any direct beneficial effect of sulphur to the growing plants.

Results for 1934, 1935 and 1937

Yield. The analyses of variance for the yield data of the 1934, 1935, and 1937 experiments, established that rust had a very great effect on yield. In each experiment the variance for rust infections greatly exceeded the error variance. The average yields for the plot series of 1934, 1935 and 1937, with the necessary differences for significance between plot series, are summarized in Table 4. To facilitate the examination of the relation of rust infection to yield, kernel weight, bushel weight, and commercial grade, the plot series in Table 4 are listed in order of increasing rust percentage.

It is evident from Table 4 that rust markedly decreased yield, the amount of decrease being directly correlated with the relative severity of rust in all years. For example, in 1937, series of plots having average stem rust infections of 5, 10, 22, 34, 51, 61, 75, and 90%, yielded 23.8, 20.1, 17.5, 15.9, 13.3, 9.6, 7.0, and 3.6 bushels per acre, respectively. In that year, when only slight traces of leaf rust developed in any of the plots, 90% infection of stem rust reduced the yield by 84.9%.

TABLE 5.—CORRELATION COEFFICIENTS FOR STEM RUST IN RELATION TO YIELD, AND THE CALCULATED REDUCTION IN YIELD FOR EACH 10 PER CENT INCREASE OF STEM-RUST INFECTION ON MARQUIS WHEAT IN 1934, 1935, AND 1937

Year	Correlation coefficient	Value of t	Reduction in yield per 10% increase of stem rust infection	
			Bushels per acre	Per cent possible yield
			bu.	%
1934	−0.6715	9.42	2.2	6.7
1935	−0.8499	15.96	1.6	7.3
1937	−0.9315	25.35	2.2	9.2

Value of t at 1% point, 2.63.

In order to examine more closely the relation of stem rust to yield a statistical study was made of the rust and yield data of the 1934, 1935, and 1937 experiments. The co-variations of stem rust infection with yield were measured by means of the correlation coefficient, and the methods used were those described by Goulden and Greaney (8) and Greaney (10). The resulting statistics are given in Table 5.

As might be expected from the average yield data for the different plot series (Table 4), a very close negative association between rust infection and yield is shown in all years. Furthermore, it was found that the regression of yield on rust was always linear. The analysis of variance method was used to test the linearity of regression and it was found that the deviations from the regression straight line were not significant. Thus, it was established that uniform increases in the percentage of stem rust infection resulted in uniform reductions in yield. The actual reductions in yield in bushels per acre, and in percentage of the possible yield, that is, the yield of Marquis wheat in the absence of rust, corresponding to each 10% increase of stem rust infection, were computed from the data of the 1934, 1935 and 1937 experiments. The values obtained are given in Table 5.

The negative correlation coefficients in Table 5 show the relative seasonal severity of stem rust for the three years 1934, 1935, and 1937. Although rust had a very detrimental effect on the yield of Marquis wheat in all years, the most severe stem rust injury occurred in 1937. In that year, each 10% of increase in stem rust reduced the yield 2.2 bushels per acre. Expressed in percentage of the average yield of the plots in which rust was almost completely controlled by dusting with sulphur (Plot series I, Table 4), the reduction of 2.2 bushels per acre represents 9.2% of the possible yield for each 10% increase in the degree of rust infection.

Kernel Weight. The results of the analysis of variance of the 1,000-kernel data for the experiments of 1934 and 1937 showed clearly that the degree of rust infection markedly affected kernel weight. The average kernel weight results for 1934, 1935, and 1937, and the necessary differences for significance between plot series, are summarized in Table 4. The results in Table 4 produce direct evidence to show that reduction in kernel weight was always directly proportional to rust severity.

In view of the importance of kernel weight in grain quality determinations, the relation between this factor and stem rust was investigated in greater detail. In the final analysis of the results of each experiment, rust percentages and the weights per 1,000 kernels of individual plots were correlated, the simple correlation coefficients being given in the upper half of Table 6.

TABLE 6.—CORRELATION COEFFICIENTS FOR STEM RUST IN RELATION TO WEIGHT OF 1,000 KERNELS AND TO TEST WEIGHT PER BUSHEL OF MARQUIS WHEAT IN 1934, 1935, AND 1937

Years	Factors correlated	Correlation coefficient	Value of t
1934	Stem rust and weight of 1,000 kernels	−0.9862	38.32
1935	Stem rust and weight of 1,000 kernels	−0.9745	26.44
1937	Stem rust and weight of 1,000 kernels	−0.9560	32.35
1934	Stem rust and weight per bushel	−0.9871	32.61
1935	Stem rust and weight per bushel	−0.9431	26.32
1937	Stem rust and weight per bushel	−0.9373	28.70

Value of t at 1% point, 2.63.

The coefficients for 1934, 1935, and 1937 are highly significant and very similar in magnitude. The exceptionally high negative correlation coefficients obtained for stem rust and kernel weight indicate that, of the agronomic characters studied, kernel weight gives the truest measure of the damage caused by stem rust. The fact that rust infection has a very detrimental effect on kernel weight is supported by the results of Neill (24), Waldron (31) and Peturson and Newton (27) who found that the reduction in yield caused by leaf rust is due chiefly to the reduced weight of the individual kernels and only to a much less extent to a reduction in the number of kernels per head. As might be expected, the kernel weight results in Table 4 closely resemble those for yield, and show that uniform increases in rust severity result in uniform decreases in the weight of 1,000 kernels.

Bushel Weight. Bushel weight, or test weight per bushel, is the standard measure of grain quality in wheat. In order to determine the effect of rust on bushel weight, determinations were made on the threshed grain from individual plots of the 1934, 1935, and 1937 experiments. The mean bushel weight results of each experiment, and the necessary differences for significance between plot series, are summarized in Table 4, and the correlation coefficients for stem rust and bushel weight are listed in the lower half of Table 6.

The analyses of variance results established that there were significant differences in bushel weight due to stem rust percentages in all years. As might be expected from the yield and kernel weight results, the results in

Tables 4 and 6 show that high stem rust percentage was always associated with low bushel weight, the reduction in bushel weight being directly proportional to the estimated stem rust severity. For example, in 1937, series of Marquis wheat plots having average stem rust infections of 5, 10, 18, 22, 34, 51, 55, 61, 75, and 90%, produced grain weighing 64, 63.5, 62, 61.5, 60, 56, 53, 51.5, 44, and 40 lb. per bu., respectively (Table 4). In that year, plot series J, the most severely rusted plots, produced grain that weighed only 40 lb. per measured bushel. The results of 1934, 1935, and 1937, are in agreement with those obtained in earlier field experiments at Winnipeg (11, 12), and show that rust, particularly stem rust, causes very substantial reductions in grain quality.

Commercial Grade. Composite grain samples from each series of plots in the experiments of 1934, 1935, and 1937, consisting of equal quantities of grain from each of the 10 plots of similar treatment, were commercially graded by an official of the Western Grain Inspection Office, Winnipeg, Man. The grades are given in Table 4.

It is evident from Table 4 that the commercial grade of Marquis was adversely affected by rust in 1935 and 1937. In these years appreciable reductions in grade occurred. The most striking effect of stem rust on grade was observed in 1937. In that year, grain from the heavily dusted plots with 5% of stem rust (Plot series I), graded Manitoba No. 1 Hard, while the threshed grain from the undusted plots with 90% of rust (Plot series J), was classed commercially as "Feed Wheat". As might be expected from the yield and bushel weight results of 1937, reduction in grade was directly proportional to the severity of rust infection.

In 1934, none of the rust severities obtained appreciably influenced the commerical grade. The grade results of that year are in agreement with those obtained in 1933 and 1936 (Table 2), and suggest that the commercial grade of wheat is not markedly affected by light infections of rust. However, the results in Table 4 show the detrimental effect that heavy infections of rust have on the commercial value of wheat, and offer further convincing evidence that inferior quality of grain induced by rust is a factor of considerable economic importance in wheat production.

DISCUSSION

During the 5-year period, 1933–37, the crop seasons of 1934, 1935, and 1937 were favourable for studying the effect of rust on yield and grain quality. In these years severe attacks of stem rust *(P. graminis Tritici)* occurred on Marquis wheat at Winnipeg. Unfortunately, leaf rust *(P. triticina)* also occurred in epidemic proportions in 1934 and 1935, and made an exact allocation of the injury caused by stem rust impossible. However, owing to the fact that Marquis is only moderately susceptible to leaf rust and highly susceptible to stem rust, there is little doubt but that by far the greater portion of the rust injury in 1934 and 1935 was attributable to stem rust. The results obtained in 1937, when leaf rust was not an important complicating factor, substantiate this conclusion. In that year,

for instance, an increase in stem rust infection from 5 to 90% reduced the yield of Marquis by 84.7% and the kernel weight 65%. The test weight per bushel of grain was reduced by 14 lb., and, in consequence, the commercial grade was lowered from "Manitoba No. 1 Hard" to "Feed Wheat".

The results of 1934, 1935, and 1937 show that stem rust alone, or in conjunction with leaf rust, was a very important factor affecting yield, kernel weight, bushel weight, and commercial grade of a susceptible variety of hard red spring wheat. The more severe the infection, the greater also was the depreciation in yield and grain quality. Of the various agronomic factors studied, kernel weight was most closely associated with stem rust, and was always inversely proportional to the percentage of infection. Kernel weight appears to constitute a very accurate index of the extent of stem-rust injury in wheat.

II. Effect of Rust on the Chemical Composition of Grain and Straw

In 1889, Harper (14) made certain chemical analyses of "rusted or frosted" wheat grown in Minnesota and found the grain of such wheat about 2% richer in protein than was normal grain. The prevalence of stem rust in Manitoba in 1904 led Shutt (28) to investigate the general effect of rust upon the wheat plant—both straw and grain. In the same year, Snyder (29), in Minnesota, analyzed the straw and grain of wheat plants that were severely affected with stem rust and of plants that were rust free. Both Shutt and Snyder found that the grain from heavily-rusted plants contained about 3% more protein than did the grain of rust-free plants. In 1915, Headden (13), working in Colorado, found that stem rust was responsible for low protein in the grain of certain wheat varieties, and in 1922 Mangels and Sanderson (20) found that rust-susceptible varieties of spring wheat produced grain that was low in protein content. Thus, the results of Headden and of Mangels and Sanderson are contrary to those of Harper, Snyder, and Shutt. In regard to the chemical composition of the straw of wheat plants, however, Shutt (28), Snyder (29), Ince (16) and Headden (13) have all reported that rusted straw contains a much higher protein content than does non-rusted straw.

The importance of the subject made it desirable to obtain more definite information concerning the effect of rust, particularly stem rust, upon protein and mineral metabolism in the wheat plant, and, accordingly, samples of grain from the 1934, 1935, and 1937 plots, and samples of straw from the 1937 plots, were analyzed for protein, phosphorus, calcium, and ash.

METHODS

Nitrogen was determined by the Kjeldahl-Gunning-Arnold Method (3). The percentage of nitrogen was multiplied by 5.7 to give the protein figure for grain, and by 6.25 for straw. Ash was determined by the official procedure for "Grain and Stock Feeds". In this procedure a 2-gram sample of grain or straw is burned in a muffle furnace at low heat, not exceeding dull redness, until free from carbon.

TABLE 7.—THE EFFECT OF STEM-RUST AND LEAF-RUST INFECTION IN DIFFERENT DEGREES OF SEVERITY ON THE CHEMICAL COMPOSITION OF THE GRAIN OF MARQUIS WHEAT IN 1934, 1935, AND 1937

(Data are means of 10 plots)

Experiment of 1934

Plot series	Stem rust	Leaf rust	Chemical composition of grain (dry matter basis)			
			Protein	Calcium	Phosphorus	Ash
	%	%	%	%	%	%
I	2	4	15.29	0.042	0.29	1.53
E	5	4	15.21	0.041	0.30	1.50
B	8	8	15.02	0.043	0.30	1.52
H	10	10	14.95	0.040	0.29	1.52
D	12	11	14.76	0.044	0.30	1.55
A	20	16	14.36	0.041	0.29	1.54
G	20	20	14.45	0.040	0.29	1.51
C	25	23	14.50	0.040	0.29	1.52
F	29	25	14.37	0.041	0.29	1.49
J	61	43	13.78	0.044	0.29	1.62
Necessary difference*	4.0	11.1	0.31	†	†	0.08

Experiment of 1935

I	3	6	19.70	0.028	0.51	2.26
E	6	9	19.62	0.025	0.51	2.35
B	12	15	19.56	0.027	0.52	2.27
H	59	48	18.75	0.028	0.51	2.35
D	65	66	18.40	0.030	0.53	2.32
A	71	68	18.32	0.028	0.52	2.39
G	72	74	18.20	0.029	0.52	2.46
C	74	71	18.44	0.027	0.53	2.45
F	80	75	17.57	0.031	0.52	2.36
J	88	77	17.11	0.029	0.53	2.39
Necessary difference*	9.6	11.7	0.45	†	†	†

Experiment of 1937

I	5	Tr.	16.03	0.041	0.42	1.94
E	10	Tr.	15.34	0.037	0.36	1.98
B	18	1	15.02	0.039	0.38	2.05
H	22	2	14.82	0.048	0.39	2.04
D	34	3	14.50	0.037	0.40	2.18
A	51	4	14.30	0.042	0.41	2.25
G	55	2	14.35	0.052	0.45	2.49
C	61	4	14.27	0.049	0.47	2.39
F	75	4	14.89	0.057	0.44	2.69
J	90	5	15.09	0.062	0.48	2.63
Necessary difference*	3.7	—	0.24	0.005	0.05	0.12

* Necessary difference, 5% level of significance, between plot series.

† Differences between plot series insignificant statistically.

Calcium and phosphorus were determined by the wet-washing procedure of Gerritz (7). It consisted of digesting with nitric and perchloric acids until a colorless solution was obtained. Calcium was then estimated by precipitation as oxalate and titration against potassium permanganate. Phosphorus was determined by the colormetric method described by King (18).

ANALYTICAL RESULTS

Grain. In Table 7 are given the average protein, phosphorus, calcium, and ash contents of grain grown under different degrees of rust severity in 1934, 1935, and 1937. It is evident from Table 7 that rust, particularly stem rust, had a very marked effect on the protein content of the grain. In all years, protein decreased as the percentage of rust increased. In the light of the necessary differences required for statistical significance, the protein results are convincing. In general, the calcium, phosphorus, and ash contents of the grain were not significantly affected by rust in 1934 and 1935, but in 1937 all three constituents increased with increased stem rust percentage.

In view of the importance of stem rust in relation to the chemical composition of the grain it was decided to investigate the results of the 1937 experiment in greater detail. In the final analysis of the results of this experiment, simple correlation coefficients were calculated between stem rust percentage and the protein content, phosphorus content, calcium content, and ash content of the grain. The significance of these relations was determined according to the test given by Fisher (5). The resulting coefficients with their t values are listed in the upper half of Table 8. All the coefficients were statistically significant, indicating that there was a close association between stem rust and the protein, phosphorus, calcium and ash contents of the grain. Protein content was negatively associated, while phosphorus, calcium, and ash contents were positively related with stem rust infection in 1937. In other words, as the severity of rust increased there was a proportional decrease in protein, and a proportional increase in the phosphorus, calcium, and ash contents of hard spring wheat. The association between stem rust and ash content was particularly marked.

TABLE 8.—CORRELATION COEFFICIENTS FOR STEM RUST IN RELATION TO THE PROTEIN, PHOSPHORUS, CALCIUM, AND ASH CONTENTS OF THE GRAIN AND STRAW OF MARQUIS WHEAT IN 1937

Plant part	Factors correlated	Correlation coefficient	Value of t
Grain	Stem rust and protein	−0.4333	4.76
	Stem rust and phosphorus	+0.5015	5.73
	Stem rust and calcium	+0.6805	9.18
	Stem rust and ash	+0.8862	18.92
Straw	Stem rust and protein	+0.5094	5.85
	Stem rust and phosphorus	+0.8054	13.44
	Stem rust and calcium	−0.6249	7.92
	Stem rust and ash	−0.8104	13.68

Value of t at 1% point, 2.63.

Straw. The analyses of variance results for the protein, phosphorus, calcium, and ash contents of the straw of the 1937 experiment showed that there were significant rust effects with respect to all four chemical constituents considered. In every instance, the variance for rust severities greatly exceeded the 1% level of significance. The mean results for the protein, phosphorus, calcium, and ash contents of the straw, with the necessary differences for significance between plot series, are summarized in Table 9. This table clearly shows the effect that stem rust, in different degrees of severity, had on the chemical composition of the straw of Marquis wheat. In 1937, the protein and phosphorus contents of the straw increased and the calcium and ash contents decreased with increased stem-rust percentage.

TABLE 9.—THE EFFECT OF STEM-RUST INFECTION IN DIFFERENT DEGREES OF SEVERITY ON THE CHEMICAL COMPOSITION OF THE STRAW OF MARQUIS WHEAT IN 1937

(Data are means of 10 plots)

Plot series	Severity of stem rust infection	Chemical composition of straw (Dry matter basis)			
		Protein	Calcium	Phosphorus	Ash
	%	%	%	%	%
I	5	5.43	0.196	0.056	9.47
E	10	5.75	0.178	0.061	9.31
B	18	6.78	0.182	0.069	8.56
H	22	6.87	0.177	0.069	9.12
D	34	7.43	0.163	0.073	8.27
A	51	8.21	0.166	0.083	8.17
G	55	8.16	0.153	0.080	8.10
C	61	8.13	0.150	0.080	7.12
F	75	8.44	0.146	0.083	7.33
J	90	8.70	0.158	0.084	7.10
Necessary difference*	3.72	0.39	0.012	0.006	1.17

* Necessary difference, 5% level of significance, between plot series.

The simple correlation coefficients between stem-rust percentage and the protein, phosphorus, calcium, and ash contents of the straw, with their corresponding t values, are given in the lower half of Table 8. From this table it is evident that there was a strong positive correlation between stem rust and protein content of the straw, and a very close negative association between stem rust and calcium and ash contents in the straw. In 1937, the phosphorus content, like the protein content of the straw, was very strongly positively related to stem rust infection.

DISCUSSION

The results of the present study produce direct evidence in support of the work of Headden (13), and of Mangels and Sanderson (20) and show that stem rust significantly reduced the protein content of the grain. They are also in accord with the results of Caldwell *et al.* (4), Phipps (26), and Peturson and Newton (27), who found that severe infections with leaf rust significantly reduced the protein content of the grain of susceptible wheat varieties.

No significant changes occurred in the phosphorus, ash, and calcium contents of grain grown under rather severe infections of rust in 1934 and 1935. These results with stem rust affected plants agree with the results

of Caldwell *et al.* (4) who found that leaf rust had no effect on the phosphorus and ash contents of the grain of certain winter wheats. The results of 1934 and 1935 with stem rust, however, were not substantiated in 1937, for in that year the phosphorus, ash, and calcium contents of the grain were appreciably increased by heavy infections of stem rust. No satisfactory explanation can be given to account for the increase of these three constituents in the grain of the 1937 crop. It is possible, however, that the total organic matter in the grain was appreciably reduced by rust in 1937, in which case a percentage increase in mineral constituents with increased stem rust infection would be indicated. The results of 1934, 1935, and 1937, showing the composition of rusted and unrusted grain (Table 7) suggest that rust infection interferes considerably more with the deposition of organic than with inorganic compounds.

The decrease in kernel weight so commonly observed in rusted wheat indicates a much reduced deposition of carbohydrates, which theoretically should increase the apparent percentage protein in the grain, providing of course that the nitrogen supply has not been interrupted in any way. Actually however, as the present results show, there is a decrease in protein percentage in the grain.

The results obtained with the 1937 straw are in full agreement with those of Shutt (28), Snyder (29), Ince (16), and Headden (13), and show that rusted straw contained a much higher protein content than did non-rusted straw. It was found that the straw of Marquis wheat increased in percentage protein and phosphorus, but decreased in calcium and ash, with increased stem-rust infection.

Protein and phosphorus are closely linked in plant metabolism, and the retention of these constituents in the straw might be due to any one or all of several factors. It might be accounted for as a direct result of the utilization of nitrogenous materials by the rust fungus, or as a result of direct interference of the fungus in translocation of the organic compounds. It is more likely, however, that the retention of nitrogen and phosphorus in the vegetative parts of the plant may be due to the combined effect of these two factors. As suggested by the studies of Caldwell *et al.*, the increased percentage of nitrogenous material in the stems and leaves of severely infected plants may be accounted for by a differential effect of the fungus on the synthesis of nitrogenous and non-nitrogenous plant food. There is the possibility, too, that the rust fungus acts as a catalyst in nitrogen metabolism and thus causes an increase in the protein content of rusted straw.

The recent work of d'Oliveira (25) suggests that the increase of nitrogen compounds in the stems and leaves of rusted wheat plants may be due to the ability of the rust fungus to fix atmospheric nitrogen. The results of his analyses of rusted and unrusted wheat and barley plants that had been grown in a nitrogen-free solution definitely point to an increase in nitrogen in the rust-infected plants. However, as d'Oliveira has pointed out, many difficulties are involved in demonstrating nitrogen fixation by an obligate parasite. It would seem that more intensive studies are necessary to show that nitrogen fixation by the rust fungi is a factor of importance in increasing the nitrogenous material of rust-infected plants.

The impaired photosynthetic activity of rusted plants, and the effect the rust fungus has in limiting the nitrogenous materials available for storage as protein in the kernels are, no doubt, the most important factors affecting the chemical composition of rust-infected wheat plants. The growth of the stem rust fungus disturbs normal plant metabolism, arrests development, and induces early ripening of the plant, thereby checking the movement of food materials to the seed. The final result is the production of straw in which still remains much elaborated plant food, and of grains that are immature, small, shrunken, and poor in protein.

III. Effect of Rust on the Milling and Baking Qualities of Marquis Wheat

METHODS

Composited samples of grain from each series of plots in the experiments of 1934, 1935, and 1937 were subjected to experimental milling and baking tests in the laboratories of the Cereal Division, Ottawa. In addition, weight per 1,000 kernels, weight per bushel, and commercial grade determinations were made for each sample. Wheat protein determinations for the composited samples were made by the Division of Chemistry, Ottawa.

Two samples were milled from each composite sample of the 1934 and 1935 crops, but only one milling was made of the 1937 samples. All samples were milled on an Allis-Chalmers experimental flour mill. The samples were prepared for milling by first scouring the wheat in an experimental scouring and aspirating machine, and then weighing out a sufficient amount to equal 2,000 gm. on a 13.5 per cent moisture basis. The first tempering consisted in bringing the wheat to a moisture content of 13% and allowing it to stand in an air-tight container for several days. Thirty minutes prior to milling, sufficient water was added to the wheat to raise the moisture content to 15.5%.

The yield of straight grade flour was determined by difference after the percentage of bran, shorts, and feeds were computed. The yellow pigment content, expressed in parts per million of carotene, was determined on each flour sample shortly after milling by the method outlined in Cereal Laboratory Methods (2) and described in detail by Geddes *et al.* (6), in which the solvent was "varnish makers" naphtha and absolute ethyl alcohol (93 parts of naphtha to 7 parts of ethyl alcohol).

The flours were baked about five weeks after milling according to the methods outlined in Cereal Laboratory Methods (2). The formula used consists of a supplementary test in which 0.3 gm. of malt extract (300° L.), 0.1 gm. $NH_4H_2PO_4$ and 0.001 gm. $KBrO_3$ are employed in addition to regular ingredients. According to Larmour *et al.* (19) and Aitken and Geddes (1) this formula gives a wide range of volumes for experimentally milled flours of Canadian Hard Red Spring wheat for different protein levels.

RESULTS

A summary of the grain quality and milling and baking results obtained with composite samples from the plots of 1934, 1935, and 1937, is given in Table 10. As the influence of rust on test weight per bushel, weight of 1,000 kernels, commercial grade, and protein content was discussed in considerable detail in Parts I and II of this paper, the relation of rust to

these grain qualities need only be mentioned here in so far as it has a direct bearing on the milling and baking properties of wheat.

TABLE 10.—THE EFFECT OF STEM RUST AND LEAF RUST IN DIFFERENT DEGREES OF SEVERITY ON THE GRAIN QUALITY AND MILLING AND BAKING QUALITY OF MARQUIS WHEAT IN 1934, 1935, and 1937. RESULTS OF TESTS WITH COMPOSITE GRAIN SAMPLES FROM 10 PLOTS OF SIMILAR TREATMENT IN EACH EXPERIMENT

Plot series	Stem rust	Leaf rust	Grain quality: Grade* (Manitoba Northern)	Grain quality: Test weight per bu.	Grain quality: Weight per 1,000 kernels	Milling and baking quality: Wheat† protein	Milling and baking quality: Straight grade flour	Milling and baking quality: Flour colour (carotene)	Milling and baking quality: Loaf volume	Milling and baking quality: Crumb texture	Milling and baking quality: Crumb colour
	%	%		lb.	gm.	%	%	ppm.	cc.	(1–10)	(1–10)
Experiment of 1934											
I	2	4	2	64.7	31.9	13.8	74.0	1.55	670	8.0	8.0
E	5	4	2	64.6	31.6	13.8	72.4	1.58	690	7.5	8.0
B	8	8	3	64.6	30.9	13.4	72.4	1.68	700	7.0	8.0
H	10	10	3	64.3	30.8	13.4	72.8	1.68	645	7.5	7.0
D	12	11	2	64.2	29.8	13.5	72.8	1.60	663	7.0	7.5
A	20	16	2	63.5	29.3	12.9	70.2	1.67	620	7.0	7.0
G	20	20	2	63.4	28.4	13.1	72.4	1.70	685	7.0	7.0
C	25	23	2	62.9	28.1	13.1	72.1	1.78	685	6.5	7.0
F	29	25	2	63.1	28.1	13.0	71.6	1.75	655	6.5	7.0
J	61	43	3	60.8	25.3	12.4	71.1	1.98	625	6.0	6.0
Necessary difference‡	4.0	11.1	—	—	—	0.17	1.27	0.028	39.4	—	—
Experiment of 1935											
I	3	6	3(d)	62.6	32.4	16.7	72.3	1.40	958	7.4	10.0
E	6	9	3(d)	62.9	32.4	16.6	73.3	1.39	954	7.6	10.0
B	12	15	3(d)	62.9	32.2	16.5	72.3	1.40	951	7.0	10.0
H	59	48	3	60.3	26.2	15.9	69.3	1.95	896	7.5	8.3
D	65	66	3	59.3	25.5	15.8	70.2	1.95	884	8.1	8.1
A	71	68	3	57.8	24.2	15.2	69.6	2.00	826	8.0	7.8
G	72	74	3	56.9	22.7	15.6	70.1	2.21	858	7.9	7.3
C	74	71	3	56.5	22.8	15.6	70.4	2.08	884	8.0	8.0
F	80	75	4(sp.)	54.5	18.7	14.7	67.5	2.45	773	7.9	5.9
J	88	77	6(sp.)	50.7	16.4	14.6	64.4	2.96	808	7.5	4.0
Necessary difference‡	9.6	11.7	—	—	—	0.28	2.15	0.035	29.5	—	—
Experiment of 1937											
I	5	Tr.	1	63.7	27.6	14.2	74.2	1.92	800	7.3	8.3
E	10	Tr.	1	63.2	26.6	13.8	72.7	2.07	771	7.0	7.8
B	18	1	1	61.6	23.2	13.3	73.7	2.26	734	6.8	7.5
H	22	2	1	60.6	22.6	13.4	72.0	2.37	729	6.8	7.3
D	34	3	2	59.2	20.2	13.1	69.9	2.67	711	6.8	6.8
A	51	4	4	55.4	17.7	12.6	70.4	2.90	658	5.5	6.0
G	55	2	5(sp.)	52.4	15.9	12.7	69.2	3.05	739	6.5	5.2
C	61	4	5(sp.)	51.0	15.0	12.6	66.6	3.41	738	7.0	5.8
F	75	4	Feed	42.3	10.9	13.1	63.2	4.01	768	6.0	4.8
J	90	5	Feed	40.0	9.9	13.6	60.2	3.83	789	5.2	3.2
Necessary difference‡	3.7	—	—	—	—	—	2.42	0.044	32.3	—	—

* (d) = diseased. (sp.) = special.
† 13.5% moisture.
‡ Necessary difference, 5% level of significance, between plot series.

In all three years, the plumpness of kernel, as reflected in test weight per bushel and 1,000-kernel weight, decreased with increased rust severity. A reduction in kernel weight was always associated with a decrease in yield of straight grade flour, and increase in yellow pigment content of the flour, and a decrease in crumb colour score of the baked loaves. Thus, the results of the present study are in full accord with the general finding in regard to the relation of plumpness of kernel to milling quality in wheat, namely, that small, shrunken wheat produces a poorer grade of flour than does large, plump wheat.

In general, wheat protein content and loaf volume decreased with an increase in rust percentage. However, an exception occurred in 1937. In that year, the most heavily rusted plots (Plot series F and J) produced grain that gave higher protein percentages than did the grain from plots having considerably lower stem rust percentages (Plot series A, G, and C, Table 10). The differences in protein content and loaf volume observed between samples of the 1934 and 1935 crops, were, with few exceptions, not great. In samples of the 1935 crop, however, there was a wide range in protein contents and loaf volumes. The grain of that year was high in protein and gave a general high level of loaf volumes and crumb texture scores. In all years, high stem rust percentage was associated with low crumb texture score.

DISCUSSION

The results of this investigation have indicated that stem rust had its greatest effect in reducing the plumpness of kernel, which in turn decreased the milling value of the wheat. This decreased milling value was reflected in reductions both in yield and grade of flour. In milling practice, it is almost impossible to produce flours of good colour from severely shrunken wheat, and the percentages of top grade flours obtained from shrunken wheat are always considerably lower than those from plumper grain.

Baking strength as judged by loaf volume measurements and crumb texture scores was not seriously affected by rust. In most cases, the baking strength of grain samples from plants heavily infected with rust compared favourably with the baking strength of grain samples from non-rusted or lightly rusted plants. It was observed that the higher protein level of the 1935 samples, as compared with the samples of the 1934 and 1937 crops, was reflected in higher baking strength. From the present results with Marquis wheat it would appear that as long as the protein level is high, even grain that is rather badly shrunken due to the effects of rust will produce flour of good baking strength. The results show that, with samples of grain having a fairly high protein level, baking strength was closely associated with protein content.

SUMMARY

A co-operative investigation was commenced in 1933 and continued until 1937 to determine the effect of rust, particularly stem rust, on the yield, quality, chemical composition, and milling and baking properties of Marquis wheat. Each year, one hundred 1/400-acre plots of Marquis were sown at Winnipeg, series of which were dusted with sulphur at different

rates and time-intervals during the growing period. In 1934, and particularly in 1935 and 1937, the plots that received no dusting treatment became heavily infected with stem rust, while a wide range in rust infection occurred in the series of dusted plots.

In 1934, 1935, and 1937, stem rust alone, or in conjunction with leaf rust, markedly affected yield, kernel weight, and commercial grade. In 1937, when leaf rust was not a complicating factor, an increase of stem rust severity from 5 to 90% reduced the yield by 84% and the kernel weight by 65%. The test weight per bushel was reduced by 14 lb., and, in consequence, the commercial grade was lowered from "Manitoba No. 1 Hard" to "Feed Wheat". Grain yield and quality were always inversely proportional to the percentage of rust infection. Of the various agronomic factors studied, kernel weight constituted the most accurate index of the extent of stem rust injury.

Samples of grain from individual plots of the experiments of 1934, 1935, and 1937, and of straw samples of the 1937 plots, were analyzed for protein, phosphorus, calcium, and ash. In all three years, the protein content of the grain decreased as the percentage of rust increased. The phosphorus, calcium, and ash contents of the grain were not significantly affected by rust in 1934 and 1935, but, in 1937, all three constituents increased with increased stem rust percentage. In contrast to the grain, it was found that the protein and phosphorus contents of the straw increased, while the calcium and ash contents decreased, with increased stem rust infection.

Milling and baking tests of composite samples of grain from the non-rusted and the variously rusted plots in the experiments of 1934, 1935, and 1937, showed that an increase in stem rust percentage was always associated with a decrease in yield of straight grade flour, loaf volume, and in crumb colour and crumb texture score. Flour colour (carotene content) increased with increased rust severity. In all three years, stem rust decreased the milling value of the wheat.

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SOME FACTORS AFFECTING THE NITRATE CONTENT OF AN ORCHARD SOIL[1]

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In 1928, an experiment was commenced at the Ontario Horticultural Experiment Station to study the extent to which apple orchard cultivation may be reduced. In 1937, Dickson (6) gave a preliminary report of this experiment. The present report deals more particularly with the nitrate nitrogen and moisture determinations made since 1936.

REVIEW OF LITERATURE

Lyon, Heinicke and Wilson (10) found that under their conditions in New York State moisture did not appear to be a limiting factor to growth and yield of apple trees. Albrecht (1) reports nitrate nitrogen production stimulated by surface cultivation in Missouri. Proebsting (11) found that cover crops on a Yolo loam soil in California did not increase either nitrogen or moisture holding capacity of the soil during a 10-year interval. Baker (2) reports a loss of total nitrogen from all of several cover crops used for 23 years in an apple orchard at Lafayette, Indiana. Millet, early rye and vetch, sown in late July or early August were the most effective cover crops in keeping up the nitrogen supply, but even these permitted a loss of approximately 20% of the original nitrogen. Collison (5) states that under a system of cultivation and the consistent use of annual cover crops it is practically impossible to build up or, in many cases, even to maintain the organic matter of an orchard soil. He suggests that these reasons are sufficient to justify the adoption of a system of orchard soil management which will involve a minimum of cultivation and a maximum use of permanent and semi-permanent covers. Baker (3) found that trunk circumference increase, terminal growth, leaf size, fruit set, total yield and size of fruit were directly correlated with total nitrogen in the soil and an abundant nitrogen supply in the tree during the growing season of 1935. Barnett (4) suggests that results obtained at Kansas indicated factors other than absorption of nitrates by tree roots to be potent in the soil nitrate relation. Filinger (9) stresses the importance of taking soil samples at regular short intervals to get a true picture of the behaviour of the nitrates in orchard soils. Fagan, Anthony and Clarke (8) found that trees in Pennsylvania receiving annual tillage with July seeding of cover crops have not done as well as those under sod rotations. Dickson (7) reports the colour of McIntosh improved and the percentage of drops reduced where the amount of nitrates in the soil was low, especially in midseason.

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EXPERIMENTAL PROCEDURE

The nitrate readings were taken in a 6-acre block of apple trees planted in 1921. The orchard was made up of Baldwin, McIntosh and Spy planted 39 feet × 39 feet with Duchess and Wealthy as fillers. The land, nearly level, is classified as Vineland Fine Sandy Loam (imperfectly drained, brown sandy loam, underlain with clay, fair in organic matter, and medium acid.) During the winter of 1935–36 all filler trees were removed except those standing in the centre of the square made by the standard trees. These were removed during the winter of 1939–40.

There were two cultural treatments. In the spring two plots were worked just sufficiently to prepare a good seed bed when a green manure crop was sown, usually around the middle of May. The other two plots were cultivated until July 15 and then seeded. In this report the first treatment is referred to as minimum cultivation and second method as regular cultivation. Each year the green manure crop was the same for all plots but has varied from year to year. In 1936 two crops of buckwheat were grown on the minimum cultivation plots and one crop on the regular cultivation plots. In 1937 and 1939 Sudan grass was grown, and in 1938 and 1940 Japanese millet.

Soil samples for nitrate nitrogen and moisture determinations were taken every two weeks beginning the first week of May and continuing until mid-October. Twenty-four borings were made on the diagonals just beyond the spread of the branches. Samples were taken at three depths, 0–6, 6–12 and 12–18 inches.

Nitrate nitrogen was determined at once by the phenoldisulphonic acid method. Moisture determinations were made by drying in an electric oven at 110° C. until constant weight was reached. Moisture and nitrate nitrogen determinations are reported on the basis of oven dry soil.

In 1938 areas designated as "R" plats were established within each plot. These "R" plats were areas 2 yards square marked off in each plot and were neither sown nor cultivated during the summer. Weeds were kept down by scraping with a hoe. Moisture and nitrate determinations were made in these areas at the same time as in the regular plots.

During 1939 and 1940 measurements of terminal growth were made. Two trees of each variety in each plot were selected; 20 terminals, growing at an angle of not more than 45°, were tagged on each tree. Measurements of elongation were taken each week starting about the middle of June and continuing until growth ceased. The average of the 20 readings for each tree was taken, and trees of the same variety and under the same cultural treatments were averaged and plotted on a graph.

RESULTS

The results of the moisture determinations for 1936–37–38 were given in a previous report on this orchard (6). The 1939–40 results confirmed those given previously; i.e., there were no appreciable moisture differences under the two treatments. At no time did moisture appear to be a limiting factor to growth or yield.

The nitrate nitrogen analyses, however, showed marked differences (Figure 1). In the minimum cultivation plots the nitrate level was low throughout the season. In the regular cultivation plots the nitrate level was low until the second or third week of June, then it began to rise, reaching

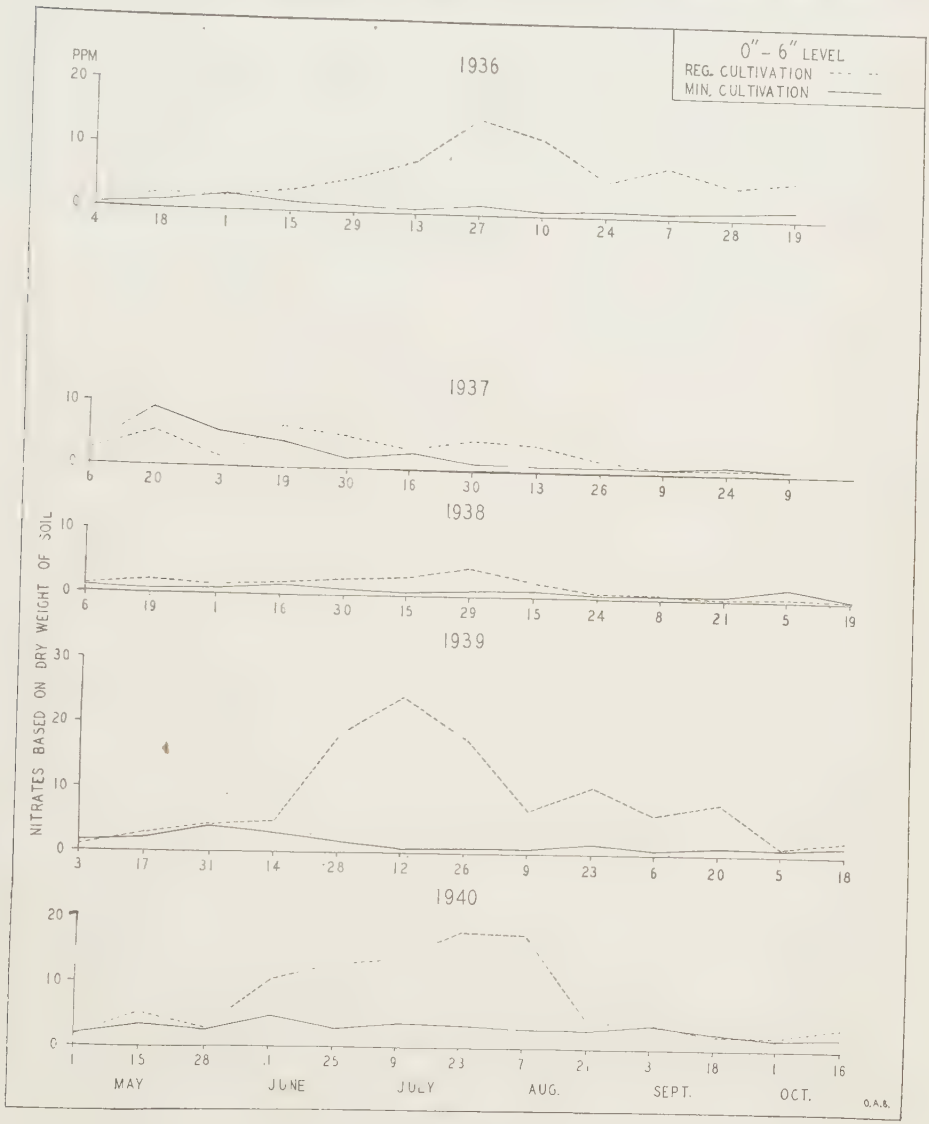

FIGURE 1. Nitrates in p.p.m. based on dry soil under regular and minimum cultivation treatments 1936-40.

a peak around the middle of July and falling gradually until it was again at a low level around the middle of August. This means there was a period of 6 to 8 weeks, mid-June to mid-August, when the nitrate nitrogen level of the regular cultivation plots was appreciably above the minimum cultivation plots. Nitrate curves for 6–12 and 12–18 inch levels, not shown

in this report, were similar to but lower than those for the 0–6 inch level and showed the same differences between the two cultural treatments (11).

Comparing the "R" plats with the regular cultivation plots during the period when the only treatment difference was cultivation there was no appreciable difference in the nitrate nitrogen over the three year period (Figure 2). In 1938 the "R" plats were slightly higher throughout the period while in 1939 the reverse was true. In 1940 two readings of the "R" plats were below and one above the regular cultivation plots. Moisture determinations showed no differences between the two treatments.

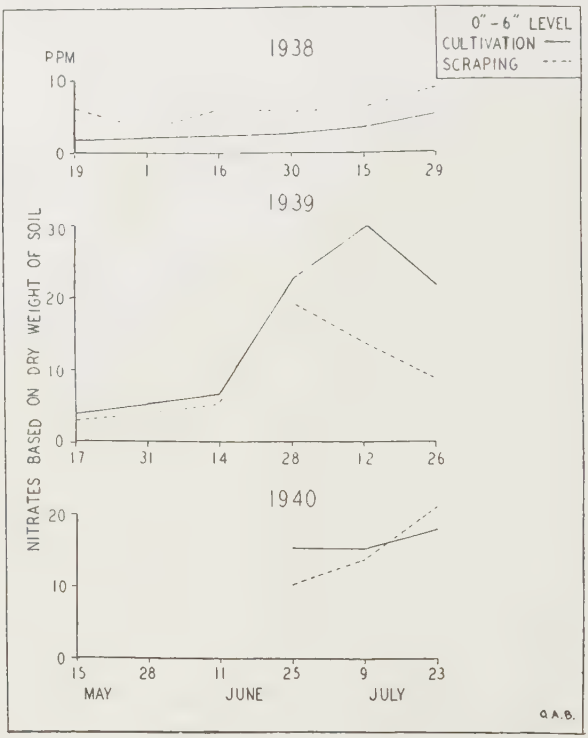

FIGURE 2. Nitrates in p.p.m. based on dry soil under cultivation and scraping 1938-40.

The difference in terminal growth under minimum and regular cultivation is quite pronounced (Figure 3). The trees under minimum cultivation made less growth and in most instances growth terminated 1 to 2 weeks sooner than in the regular cultivation plots.

DISCUSSION

In this experiment soil moisture did not appear to be responsible for any of the differences between minimum and regular treatments. In July the soil under the heavy growth of green manure crop in the minimum cultivation plots contained practically as much moisture as the soil under cultivation up to this time. At no time did either green manure crop or trees appear to suffer from lack of moisture.

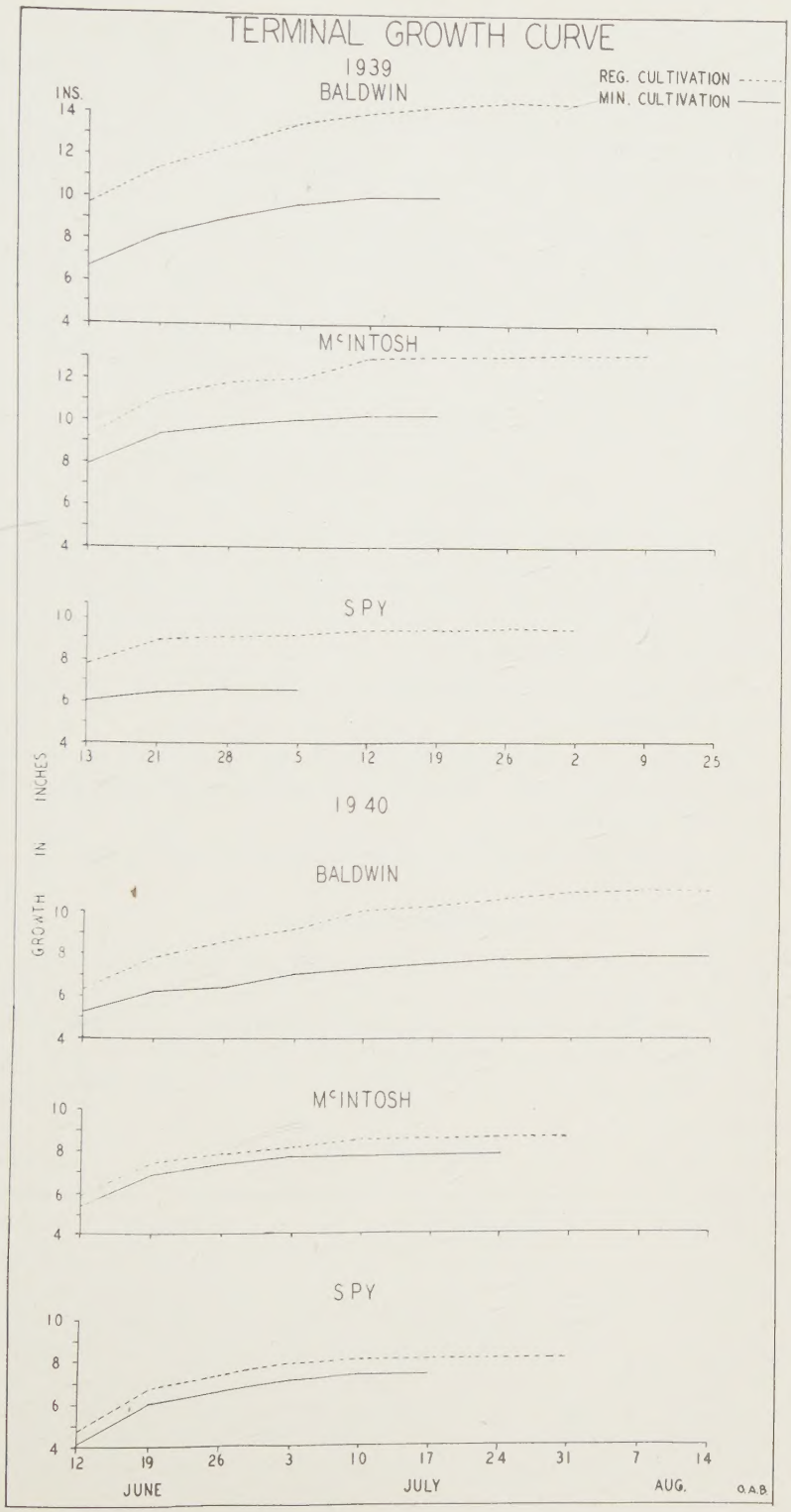

FIGURE 3. Terminal growth in inches of Baldwin, McIntosh and Spy under regular and minimum cultivation, 1939 and 1940.

The low nitrate nitrogen level throughout the season on the minimum cultivation plots was apparently largely due to nitrates being used by the green manure crop. In the regular cultivation plots the nitrate nitrogen level was higher for the 6- to 8-week period from mid-June to mid-August. The higher nitrate level delayed fruit maturity, reduced fruit colour and caused greater loss from dropping in McIntosh (7). A system of green manuring that will keep the nitrate level low but still leave enough for the trees to make normal growth appears to be the ideal.

Cultivating the soil during the latter part of May until the middle of July as compared with keeping the weeds down by scraping did not exert a consistent effect on the nitrate level or moisture supply under the conditions of this experiment. This would seem to indicate that some of the reasons given for cultivation, viz., moisture conservation and stimulation of nitrification, do not always hold true.

CONCLUSIONS

1. There were marked differences in the nitrate nitrogen content of the soil under minimum cultivation (seeded May 15) and regular cultivation (seeded July 15). Under minimum cultivation the nitrate nitrogen content of the soil was appreciably lower during late June, July and early August than under regular cultivation.

2. There were no appreciable differences in soil moisture between the two cultural treatments.

3. Cultivating the soil during May, June, and early July as compared with scraping the soil did not consistently increase or decrease the nitrate nitrogen or moisture supply.

4. Terminal growth was increased and prolonged in the regular cultivation plots.

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BOOK REVIEW

"Fruit Crops" Principles and Practices of Orchard and Small Fruit Culture by T. J. Talbert and A. E. Murneek. 345 pages with 112 illustrations. Lea and Febiger, Philadelphia. ($3.75).

The object of this book is to set forth a complete and modern view of the culture of fruit crops in a manner suitable for undergraduate students of agricultural colleges and as a guide for progressive fruit growers. The authors have followed the plan of presentation used successfully for the past twenty years in teaching and investigational work at the University of Missouri and at several other colleges of agriculture and as a result the subject matter is well-balanced. The outstanding feature of this treatise is that much practical information upon every phase of fruit growing has been incorporated. Fundamentals that influence and determine the success of fruit growing are considered but the emphasis for the performance of certain practices is based on reasons for them rather than rules.

In Chapter I, "Fruit Growing as an Occupation" the reader is given a bird's eye picture of some of the problems confronting the prospective planter. In the early chapters much space is devoted to methods of propagation by hardwood cuttings, layering, budding and grafting and the instructions on how to perform the various operations are well illustrated. In the chapter on "Soils and Plantings" soil structure is rightly given prominence. Irrigation and drainage are thoroughly discussed. Soil management and fertilization is treated in light of present day knowledge of plant nutrition and the necessity of an intelligent soil management program is stressed. Methods of tree pruning as it affects different deciduous fruit trees are discussed and the reader is left in no doubt that a clear understanding of tree habit and response is of far greater value than any set of rules. In Chapters X, XI, XII the necessity for the proper control of insects and diseases in the economic production of the various fruits is stressed and useful information is included on the various spray materials and methods of application. At Chapter XIII, the book passes from general considerations and practices to the particular requirements of the various fruits. The information on pome fruits, stone fruits, grape, strawberry, cane and bush fruits and nut culture is carefully prepared. The section on harvesting, grading, packing and marketing will chiefly interest the commercial grower. In view of the thoroughness which the authors exercised in all other respects it is to be regretted that no mention is made of refrigerated cold and gas storage of fruits.

This text is a practical, scientific and effective guide to the successful production of fruits. It will serve as a valuable textbook for the student and give much helpful information to the commercial grower. Even for the Pomologist the book will be found very convenient for quick reference.

—D. S. Blair.